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ENVIRONMENTAL RESTORATION PROGRAM

Annual Hydrologic Data Summary for the Whiteoak Creek Watershed Water Year 1990 (October 1989—September 1990)

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Authors: D. M. Borders, S. M. Gregroy, R. B. Clapp, B. J. Fredrick, G. K. Moore, J. A. Watts, C. C. Broders, A. T. Bednarek

Abstract: Characterization of the hydrology of the WOC watershed. Includes discharge and runoff, surface water quality, radiological, and chemical contamination of sediment data, and descriptions of the outfalls to the WOC flow system. Includes meteorological data. A table summarizing sources of WOC monitoring data, including location, chemical evaluated, and contact is provided.

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Environmental Restoration Division
ORNL Environmental Restoration Program

ANNUAL HYDROLOGIC DATA SUMMARY FOR THE WHITEOAK CREEK WATERSHED: WATER YEAR 1990 (OCTOBER 1989-SEPTEMBER 1990)

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ABBREVIATIONS

ASEMP	Active Sites Environmental Monitoring Program
ATDL	Atmospheric Turbulence and Diffusion Laboratory
BMAP	Biological Monitoring and Abatement Program
BMP	Best Management Practices
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet per second
CWA	Clean Water Act
DAS	Data Acquisition System
DCP	Data Collection Platform
DIMS	Data and Information Management System
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DOE	Department of Energy
ECS	Environmental Compliance Section
EDT	Explosives Detonation Trench
EPA	Environmental Protection Agency
ERFU	Environmental Restoration and Facilities Upgrade
ERP	Environmental Restoration Program
ESD	Environmental Sciences Division
ESP	Environmental Surveillance and Protection Section
ETF	Engineering Test Facility
EWB	Emergency Waste Basin
FFA	Federal Facilities Agreement
FS	Feasibility Study
gpm	gallons per minute
GPP	General Plant Project
GPPM	Groundwater Protection Program Manager
GWPP	Groundwater Protection Program
HCTF	Hill Cut Disposal Test Facility
HEC	Hydrologic Engineering Center
HFIR	High Flux Isotope Reactor
HHMS	Hydrostatic Head Monitoring Station
HRE	Homogenous Reactor Experiment
HRT	Homogenous Reactor Test
HSG	Hydrologic Soil Group
ICM	Interim Corrective Measures
ICP	Inductively Coupled Plasma
IEA	Internal Environmental Assessment
IIA	Information Integration and Analysis
ISV	In-Situ Vitrification
IWMF	Interim Waste Management Facility
LLW	Low Level Waste
MB (MBR)	Melton Branch
mgd	million gallons per day
MMES	Martin Marietta Energy Systems

MSL	Mean Sea Level
MSRE	Molten Salt Reactor Experiment
NEPA	National Environmental Policy Act
NHF	New Hydrofracture Facility
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRWTF	Non-Radiological Wastewater Treatment Facility
NSPP	Nuclear Safety Pilot Plant
NWT	Northwest Tributary
OECD	Office of Environmental Compliance and Documentation
OEHP	Office of Environmental and Health Protection
OHF	Old Hydrofracture Facility
ORRHAGS	Oak Ridge Reservation Hydrology and Geology Study
ORHSP	Oak Ridge Hydrology Support Program
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
ORRHAGS	Oak Ridge Reservation Hydrology And Geology Studies
PA/SI	Preliminary Assessment/Site Investigation
PCB	Polychlorinated Biphenyl
PWTP	Process Waste Treatment Plant
RA	Remedial Action
RAP	Remedial Action Program
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RFA	RCRA Facilities Assessment
RFI	RCRA Facility Investigation
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
S&M	Surveillance and Maintenance
SARA	Superfund Amendments Reauthorization Act
SCS	Soil Conservation Service
SDWA	Safe Drinking Water Act
SLB	Shallow Land Burial
STP	Sewage Treatment Plant
SWMU	Solid Waste Management Unit
SWSA	Solid Waste Storage Area
TARA	Test Area for Remedial Action
TD	Technology Demonstration
TDEC	Tennessee Department of Environment and Conservation
TM	Technical Memorandum
TOC	Total Organic Carbon
TOX	Total Organic Halides
TRC	Total Residual Chlorine
TRE	Total Rare Earths
TRU	Transuranics or Transuranium Processing Facility
TSS	Total Suspended Solids
USGS	United States Geological Survey
VOC	Volatile Organic Compound

WAG	Waste Area Grouping
WOC	Whiteoak Creek
WOCE	Whiteoak Creek Embayment
WOCHW	Whiteoak Creek Headwater
WOD	Whiteoak Dam
WOL	Whiteoak Lake
WPCP	Water Pollution Control Program

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The authors acknowledge the technical review and helpful suggestions of Diana S. Wickliff and William McMaster. McMaster also provided information on the Oak Ridge Reservation Hydrology and Geology Studies (ORRHAGS) program and the Oak Ridge conceptual model. Dennis Wolf and Mark Tardiff provided tables on "Data availability from ESP/IIA on White Oak Creek Watershed." Mary Alice Faulkner helped with data retrieval and GIS mapping, and Linda Allison provided information on U.S. Geological Survey (USGS) streamflow and precipitation data. Arnold Hunley provided data for solid waste storage area 7 (SWSA 7) and SWSA 7 Area well water levels. T. A. Fontaine provided information on sediment monitoring and hydrologic response to extreme events. Charlie Valentine and Elizabeth Wright provided assistance on National Pollutant Discharge Elimination System (NPDES) (application for renewal, stormwater sampling program, and outfalls). Arnold Beal provided a description of the new Environmental Surveillance Program (ESP) instrumentation/computer system for surface water monitoring stations that is discussed in this report. Diana Wickliff and Tom Ashwood provided assistance with and explanation of the Active Sites Environmental Monitoring Program (ASEMP). Several others provided information or guidance for this report in many ways. Russell Hirst, ORNL Environmental Restoration Program, provided editorial assistance. We thank all of them; without their assistance, this report would have been difficult to prepare.

ADDENDUM

Those familiar with the Oak Ridge Reservation (ORR), particularly the watershed within which the Oak Ridge National Laboratory (ORNL) lies, will observe that the name of the watershed, and hence the creek that drains it, commonly referred to as White Oak, appears as a single word (Whiteoak) in this report. This departs from past usage by ORNL. For much of the nearly fifty-year history of the ORNL, the customary usage has been White Oak Creek. However, Whiteoak is the official name of the creek and watershed. This is evident on the Tennessee Valley Authority's (TVA's) S-16A map of the Oak Ridge Area (revised in December 1987 - based on the 1927 North American Datum) which is the standard base map for ORNL. This is supported by the U.S. Department of Interior, Geological Survey's (USGS's) annual water resources data reports for Tennessee since 1950 and TVA's "Bethel Valley Quadrangle" topographic map of which the original is dated 1953. In addition, according to Roger Payne, the Executive Secretary for Domestic and Geographic Names, "The official federal position on the name of the feature is 'Whiteoak Creek'; the orthography is Whiteoak (one word). To change it would take a formal decision by the Board on Geographic Names whose policy is public law created by Congress, in its present form, in 1947. The law, in its original form, was enacted by Presidential Executive Order in 1890. One purpose of the law is to prevent the occurrence of what has happened at ORNL: inconsistent usage of the name of a geographic feature by various federal agencies. Furthermore, to strictly adhere to regulations, use of the two-word form is illegal and outside use (publication) by federal agencies constitutes a non-conformance to regulations. Whiteoak Creek is the official, legal name and is binding on all federal agencies." (Roger Payne, Executive Secretary for Dometic and Geographic Names, personal communication to D. M. Borders, University of Tennessee, September 19, 1991). The authors of this report feel it is their obligation to adopt the correct usage of the name of the creek and watershed from which the majority of their data come.

EXECUTIVE SUMMARY

This report summarizes, for the Water Year 1990 (October 1989—September 1990), the dynamic hydrologic data collected on the Whiteoak Creek (WOC) Watershed's surface and subsurface flow systems. These systems affect the quality or quantity of surface water and groundwater. The collection of hydrologic data is one component of numerous, ongoing Oak Ridge National Laboratory (ORNL) environmental studies and monitoring programs and is intended to

1. characterize the quantity and quality of water in the flow system,

2. plan and assess remedial action activities, and

3. provide long-term availability of data and assure quality.

Characterizing the hydrology of the WOC watershed provides a better understanding of the processes which drive contaminant transport in the watershed. Identifying of spatial and temporal trends in hydrologic parameters and mechanisms that affect the movement of contaminants supports the development of interim corrective measures and remedial restoration alternatives. In addition, hydrologic monitoring supports long-term assessment of the effectiveness of remedial actions in limiting the transport of contaminants across Waste Area Grouping boundaries and ultimately to the off-site environment. For these reasons, it is of paramount importance to the Environmental Restoration Program (ERP) to collect and report hydrologic data, an activity that contributes to the Site Investigatios of ADS 322.

The majority of the data summarized in this report are available from the Remedial Action Program Data and Information Management System data base. Surface water data available within the WOC flow system include discharge and runoff, surface water quality, radiological and chemical contamination of sediments, and descriptions of the outfalls to the WOC flow system. Climatological data available for the Oak Ridge area include precipitation, temperature, humidity, wind speed, and wind direction. Information on groundwater levels, aquifer characteristics, and groundwater quality are presented. Anomalies in the data and problems with monitoring and accuracy are discussed. Appendices contain daily precipitation measurements, daily discharge at surface water monitoring stations, rating curves for all hydraulic control structures described in this report, and groundwater well water level summary statistics for levels of groundwater in the 126 wells located in the WOC watershed from which data were collected in Water Year 1990.

1. INTRODUCTION

This report is the third in a series of annual reports prepared to summarize the hydrologic data collected on and in the vicinity of the Whiteoak Creek (WOC) watershed (Fig. 1) and has been prepared as part of the Environmental Restoration Program (ERP) at Oak Ridge National Laboratory (ORNL), established in 1985 to provide comprehensive environmental management of areas where research, development, and waste management activities have resulted in residual contamination of facilities or the environment (initiated to remediate sites contaminated by spills or past disposal practices). WOC drains the ORNL and receives radioactive and nonradioactive effluents (treated and untreated) from Laboratory activities as well as leachates from subsurface waste storage areas in use since the early 1940s. Sherwood and Loar (1986) summarized the available information on hydrogeological and ecological characteristics of the WOC flow system and the nature and quantity of contaminants released into and from the system. Preparation of previous annual summaries of hydrologic data were prepared in response to Sherwood and Loar's recommendation that the hydrology of the WOC watershed be characterized in order to better understand trends in both temporal and spatial patterns of the watershed. This annual report supports that need and provides the sources of data needed for long-term assessment of the effectiveness of remedial restoration activities.

1.1 PURPOSE AND SCOPE

This report documents hydrologic data collected on the WOC watershed for Water Year 1990 (October 1, 1989—September 30, 1990). The collection of hydrologic data is an integral component of numerous ongoing ORNL environmental studies and monitoring programs and is designed to help (1) characterize the quantity and quality of water in the flow system, (2) plan and assess remedial action activities, (3) provide long-term data availability and quality assurance, and (4) support long-term measures of contaminant fluxes at a spatial scale to provide a comprehensive picture of watershed performance that is commensurate with future remedial actions. The report summarizes the available dynamic hydrologic data collected during the water year, along with information collected on the surface and subsurface flow systems which affect the quantity or quality of surface and groundwater. In addition, it describes a number of relevant ORNL programs and ERP projects which produce information on hydrologic characterization or related data.

The first annual summary of hydrologic data for the WOC watershed was issued as a Remedial Action Program (RAP) internal report. Reports prepared in this series have restricted distribution and cannot be cited. The second report (Borders et al. 1989), issued in 1989 as an ORNL Technical Memorandum (ORNL/TM), has unlimited distribution and can be cited in any document. Portions of the current report have been taken from the 1989 report. In addition to presenting data collected during the 1990 water year, we have attempted to summarize data collected over several years to show trends in both spatial and temporal scales and to partially fill the data gap, for the period May 1, 1988-September 30, 1989, which has not previously been reported on because of problems with instrumentation and data collection at the various monitoring stations.

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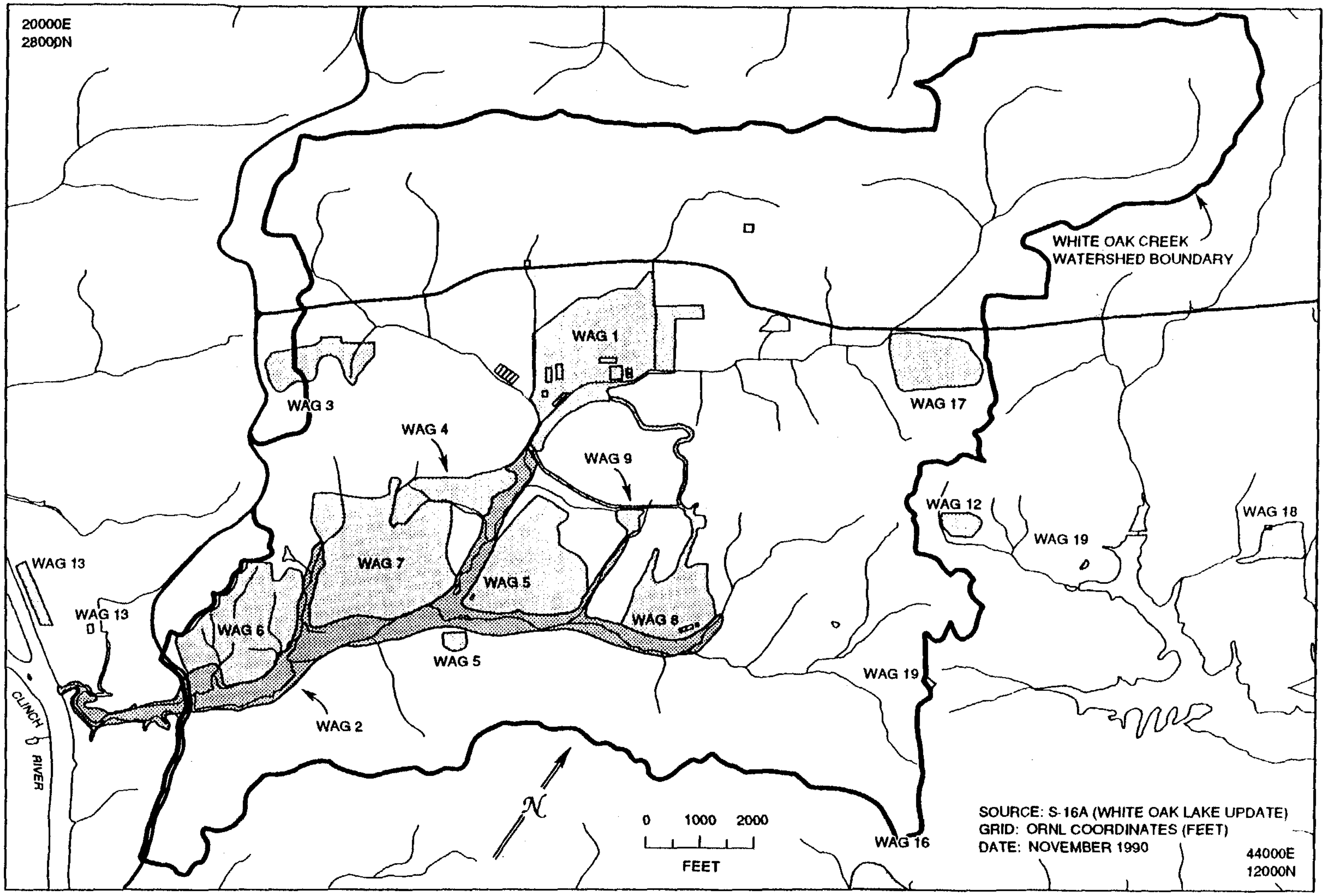

Fig. 1. Map of the Whiteoak Creek Watershed with waste arca groups (WAGs) shown.

1.2 ENVIRONMENTAL RESTORATION PROGRAM

The ERP at ORNL remediates sites contaminated by spills or past waste disposal practices. The remediation efforts are intended to protect human health and the environment off-site, both during and after ORNL facility operations, and on-site after institutional control ceases. A listing of known active and inactive waste management areas, contaminated facilities, and potential sources of continuing releases to the environment was prepared for the ORNL Resource Conservation and Recovery Act (RCRA) Facilities Assessment (RFA)(March 1987). The RFA identified approximately 250 sites (Solid Waste Management Units [SWMUs] to be considered for possible remediation. Since that time, the number of SWMUs has grown to approximately 400. Because of the large number of SWMUs, ORNL proposed that they be combined into 20 Waste Area Groupings (WAGs). Each WAG was selected to contain sites with geographical proximity and common hydrological characteristics. Eleven of these WAGs lie at least partially within the WOC watershed, and have the potential for impact on the environment of, and effluents from, the watershed. These WAGs are subject to the following ERP processes (Clapp et al. 1991a):

Preliminary Assessment/Site Investigation (PA/SI) - Contaminated or potentially contaminated sites will be identified and assessed to determine if further action is necessary.

Remedial Investigation (RI) - If the PA/SI determines that the site justifies additional study or if there is insufficient information to evaluate the site, an RI will be conducted to determine the nature and extent of contamination.

Feasibility Study (FS) - Remedial alternatives will be evaluated and remedial action recommendations made.

Remedial Design (RD) - Plans and specifications will be prepared for the remedial action recommended in the FS.

Technology Demonstrations (TDs) - Technologies will be identified that need to be developed and/or demonstrated for application at ORNL sites.

Remedial Action (RA) - Selected remedial alternatives will be implemented.

Surveillance and Maintenance (S&M) - Contaminated sites, prior to remediation, will be surveyed periodically, and maintenance activities performed.

Interim Corrective Measures (ICMs) - At any stage of the above process, ICMs may be defined that require accelerated remediation due to health and environmental risks.

Principally, this report describes and provides sources of hydrologic data for Environmental Restoration activities which use monitoring data to quantify and assess the impact from releases of contaminants from ORNL WAGs. Also, it briefly summarizes and describe specific components of the ERP and tasks providing hydrologic and contaminant flux data. In addition, this report reviews existing programs outside of ERP which provide hydrologic data that could be benefit to ERP's goals.

1.2.1 Environmental Restoration Monitoring and Assessment

The Environmental Restoration Monitoring and Assessment (ERMA) Program at ORNL was established to coordinate and integrate short-term and long-term monitoring for facilities and areas managed by the ERP (Clapp et al. 1991b). The ERMA Program is responsible for the identification of monitoring needs by environmental restoration (ER) programs, identifying data gaps, coordinating data acquisition among the various data collection groups, and developing and implementing data collection activities where necessary. The ERMA Program will produce regular periodic data summaries identifying spatial and temporal trends, interpret those trends, and assess the releases from contaminated WAGs. In addition, the ERMA Program will ensure that the proper information is collected to satisfy the needs of the ERP in a consistent manner, and that data quality objectives are met.

Data quality objectives will be identified with the assistance of data users within the ERP. Because some data collection activities are conducted for brief periods to meet short-term needs of data collection groups, ERMA will develop long-range plans to ensure continuity in monitoring data deemed to be essential to the ERP. When resources are expected to preclude collection of important data, ERMA will inform ER management so that reallocation of resources can be considered.

The ER management has identified the need for the ERMA program in order to provide an integrated, comprehensive summary and interpretation of monitoring results to assist decision making within the ERP and to enhance communication with regulators. In addition, ERMA will meet the monitoring needs of the functional groups within the ERP. Needs will be identified by creating formal and informal linkages with other ER groups. An ERMA oversight committee has already been formed to provide input and to review monitoring plans, activities, and results.

Monitoring efforts focus is on dissolved and particle–bound contaminant transport. Monitoring tasks are divided into two groups: (1) surface water and (2) groundwater data collection. Information will be exchanged among staff responsible for these two areas. The basic spatial unit for monitoring will be the WAG. Data from WAG–specific studies will be summarized in order to identify and quantify contaminants present in the WAG.

There are four overall task objectives for the ERMA:

1. Coordinate monitoring activities to quantify water and contamination fluxes from WAGs and the ORNL site.

2. Develop and implement data sampling and analysis plans for data needed for the ER program and not collected by others.

3. Directly investigation and evaluate the mobility, transport, and fate of contaminants in support of Objectives 1 and 2.

4. Summarize monitoring data periodically, identify spatial and temporal trends, and augment the interpretation of data using the results of the directed studies. The purpose

of summary reports is to provide a comprehensive, integrated analysis of contaminant movement in the WOC watershed and from WAGs located outside the watershed.

The ERMA program will produce an annual baseline Environmental Restoration Monitoring Report for the ORNL site at the end of each fiscal year, reporting data for the previous calendar year. This hydrologic data summary report for the WOC watershed will be incorporated into the ERMA baseline monitoring report next year. Contaminant concentration data collected at surface water and groundwater monitoring sites, seep studies, and storm sampling will be summarized. Utilizing the information from the directed studies and RI/FS reports, trends will be identified and data will be interpreted based on our present understanding of mobilization, transport and fate of contaminants.

1.2.2 Site Investigation

The Site Investigation (SI) component of the ERP has the following primary goals (Clapp et al. in press):

1. Perform the basic PA/SI activity. This includes maintaining a list of all potential remediation sites at ORNL and the respective status of each within the ER process. Remediation activities are prioritized based on site-specific data, monitoring results, and risk assessments. This provides a logical sequence for ICMs and remediation. In addition, data packages are developed for each WAG to identify, evaluate, and interpret existing data to guide further monitoring and characterization efforts.

2. Perform monitoring and data collection that are not WAG-specific: This includes developing a monitoring program in cooperation with ORNL compliance staff and assessing long-term effectiveness of remedial activities.

3. Perform special studies to support goals 1 and 2. The objectives of these special studies are to identify and quantify contaminant transport mechanisms to provide insight and guidance for remedial action decisions.

Site investigation activities for environmental restoration are being conducted in order to reduce the uncertainties associated with characterizing ORNL WAGs. These uncertainties are related to lack of information about the type and quantities of waste disposed at ORNL and to the complexity of the hydrologic regime on the Oak Ridge Reservation. The primary uncertainties associated with characterizing ORNL WAGs are (1) the source term, (2) secondary sources, (3) hydrologic transport mechanisms, and (4) determining near-term and long-term risks based on sources and transport mechanisms. A brief description of a number of special studies which have provided, or will provide pertinent hydrologic data or descriptions of hydrologic transport mechanisms follows.

1.2.2.1 Sediment monitoring plans

Contaminants of key concern in the WOC watershed, particularly ^{137}Cs and ^{60}Co, are particle-reactive and accumulate in and move with aquatic and floodplain sediments. In order to determine potential off-site radiation exposures, it is critically important to characterize the nature and extent of contamination, monitor sediment movement within and out of the watershed, and develop the capability to predict contaminant transport under a range of conditions, including land use scenarios imposed by future remediation. Therefore, a sediment transport monitoring program is central to the goals of the WAG 2 RI and the Clinch River RFI. Each project includes a vital component dealing with monitoring and modeling sediment transport. The WAG 2 and Clinch River programs will coordinate efforts, where possible, to avoid duplication and to establish a working link between the WOC watershed and the off-site environment.

A system for routinely monitoring suspended sediments and their associated contaminant burdens will be developed in cooperation with the Environmental Surveillance and Protection (ESP) compliance personnel (T. A. Fontaine, Oak Ridge National Laboratory, personal communication to D. M. Borders, University of Tennessee, August 1991). The system will be designed to meet requirements of the new Department of Energy (DOE) Order 5400.5 for monitoring sediment transport and the associated potential human dosage. Intensive monitoring of storm events may be required to evaluate flow-dependent sampling protocol. The information from this system will be used to identify major sources of (and sinks for) contamination carried by sediments, to investigate the mechanics of sediment transport, and to predict the potential impact of various ICMs and remediation activities.

Intensive monitoring will be conducted to quantify and evaluate the factors contributing to the movement of contaminated sediments during storms. For contaminated sediments in Whiteoak Lake (WOL), the Whiteoak Creek Embayment (WOCE), or in the WOC channel and floodplain, this will involve estimating the forces required to resuspend or erode the sediments. In addition, site investigators will study the processes of adsorption or desorption of chemicals on sediment particles. As these processes are defined, estimates of the fate of contaminants in the system can be improved.

Models will be developed or modified and then calibrated to predict sediment transport in the WOC watershed (H. L. Boston, Oak Ridge National Laboratory, personal communication to D. M. Borders, University of Tennessee, August 1991). The objective is to develop relationships between discharge and contaminant mass flux (sediment transport) at various points in the flow system to (a) predict contaminant transport during extreme events, and (b) evaluate the influence of corrective measures on contaminant transport, both during and after implementation. Work on this task will be coordinated with and influenced by special sediment dynamics investigations of the hydrologic response to the kind of extreme events described below.

1.2.2.2 Hydrologic response to extreme events

Floods of moderate to extreme magnitude (i.e., of 10-year or less probability return periods) have the potential to cause significant damage in the WOC watershed. There are a number of potential mechanisms by which these events may cause material, physical, or environmental harm. Floods transport contaminants from ORNL facilities or waste disposal sites causing adverse effects on human health and the environment, incurring economic loss, and disrupting operations due to structural damage to facilities in the floodplain. Resuspension of contaminated sediments from WOL, the channels and floodplain of WOC, and the WOCE represents a significant potential for environmental degradation to the off-site environment (Clinch River). Structural damage and disruption of operations could be caused by high water velocities, erosion and deposition of sediments, and submergence of structures, equipment, instrumentation, etc. by high water. During extreme conditions, overtopping of Whiteoak Dam (WOD) could occur, damaging the highway crossing the top of the dam, the sediment control structure at the mouth of WOC, and potentially, WOD structure.

A draft plan for investigating hydrologic response to extreme events at ORNL has been developed by T. A. Fontaine (personal communication to D. M. Borders, University of Tennessee, August 1991). The plan proposes methods to evaluate the environmental and structural impact that could be expected to occur during floods ranging from moderate (e.g., a 10-year event) to extreme (e.g., a 50-year event up to the probable maximum flood). The objectives of the plan are to (1) develop the capacity to predict the movement of contaminants in the WOC watershed during moderate to extreme events, (2) develop the capacity to predict the movement of contaminants out of the watershed into the Clinch River during these events, and (3) make predictions for a variety of conditions in the watershed including predictions of existing conditions, those expected to occur during remediation activities, and future conditions remediation activities are completed.

The plan includes the following four phases:

1. Identify unknowns by defining the natural hydrology, sources of contamination, and processes controlling contaminant transport and fate of mobilized contaminants in the WOC system. Information will be derived from field surveys, historical records, and assumptions made to allow the initial modeling studies to be conducted. Initial modeling results will be used to determine additional data needs and for setting priorities for collecting the remaining information.

2. Select and develop models to simulate the hydrology of the WOC system, the transport of contaminants and sediments, and the chemical interactions between particles and contaminants.

3. Develop a field data collection system to obtain data for modeling. Minimum data requirements have been identified for hydrologic data, bed and suspended sediment properties, and data for contaminant chemistry.

4. Simulate response from various floods. Using simulations based on existing and future conditions, the models will provide estimates of impact to the WOC watershed and the off-site environment resulting from a range of flood magnitudes.

This task is closely related to the investigation of sediment dynamics because sediment transport is proportionally related to stream discharge. That is, as stream flow rates and velocities increase, the sediment transport capacity of streams increases. Therefore, over time, the majority of sediment transported within and out of the watershed occurs during a few large storm events. The size of floods to be considered for this task will have a broad range. Relatively frequent events (e.g., one or two-year recurrence interval), which primarily cause erosion, will be very important because historical data for events of this magnitude will be readily available for model calibration. Extreme events (e.g., 100-year or lesser frequency recurrence interval), which could cause structural damage, extensive erosion, and possibly cause WOD to fail, will also be considered. The task began with a qualitative assessment and the identification of vulnerable systems within the ERP. The modeling task is expected to be a two-year activity.

1.2.2.3 Station upgrade and maintenance

The integrity of the system that monitors surface water discharge on the WOC watershed has been deteriorating for several years due to the unmitigated deposition of sediments in stilling pools, inadequate design and lack of calibration of engineered flow measurement devices, and general lack of a consistent and comprehensive monitoring station and channel maintenance program. In addition, the limited length and continuity of stream discharge records hinders the performance of stream flow analyses (e.g., duration and frequency analyses). This section addresses the problems with monitoring surface water discharge and collecting data at sites in the WOC watershed and vicinity. Accurate continuous discharge measurements are critical to the ERP's goal of quantifying and characterizing contaminant discharges from waste sites at ORNL for future remedial actions.

In the early 1980s, the primary surface water monitoring stations on WOC and Melton Branch (MB), above their confluence and at WOD, were upgraded (redesigned) for improved discharge measurements and water quality sampling. At each site, the engineered hydraulic control (i.e., flow measurement structure) consists of separate low-flow and high-flow devices (i.e., weirs) for measuring discharge. The low-flow weirs were designed to accurately measure a range of flows from the minimum expected to occur at the respective site to a given flow rate considerably higher (by a factor of two or more) than wet season base flow rates. The high-flow weirs were designed to measure flows in a range from slightly less than the maximum low-flow weir discharge to maximum discharges associated with a moderate to extreme flood event of approximately 25 to 100-year return periods. Instrumentation at these sites was designed to detect stages (water levels) above the weir crests and convert the measurements to discharge values. During significant storm events, when streamflow increases and the low-flow stage exceeds the maximum value (corresponding to the capacity of the weir), the instrumentation automatically switches over to the high-flow weir to measure discharge until streamflow decreases to the point where the capacity of the low-flow weir is no longer exceeded. At this point, the instrumentation automatically switches back to the low-flow device.

The original stage-discharge relationships for these three monitoring stations were developed from scale model tests. In 1984-85, the low-flow control devices (sharp-crested V-notch weirs on WOC and MB and a sharp-crested trapezoidal weir at WOD) were field rated by volumetric measurements made over a range of flows. These field ratings, incorporated into the instrumentation to provide more accurate discharge data, indicated that the original model calibrations were significantly in error. The high-flow control devices (broad-crested weirs) have never been field-rated to verify or adjust the stage-discharge relationships for determining discharge. However, standard theoretical derivations for each site indicate high-flow stage-discharge relationships significantly disagree with the original relationships still being used. For example, the maximum discharge at WOD, for a stage of 2.74 m (9 ft), calculated by the original scale model relationship and the theoretical relationship, is 2005 and 1860 cfs, respectively. This suggests a 7.8% overestimation of the capacity of WOD. However, unknown factors, which can only be accounted for only by field calibration, potentially increasing this error in calculation, coupled with the inherent errors and uncertainties in stage measurement, may cause in current errors in discharge measurement at WOD in excess of 10%. This would exceed regulatory guidelines.

Similar conditions exist at the WOC and MB monitoring stations. However, at the MB station, much greater errors in discharge measurement occur under high-flow conditions due to submergence (drowning out) of the broad-crested weir. This is caused by the channel downstream from the monitoring station becoming constricted. At high flows, the tailwater, unable to flow freely in the inadequate channel, backs up and rises above the crest of the weir, drowning out the structure. At some critical degree of submergence (the ratio between the depth of water over the weir crest on the upstream side to the depth of water above the weir crest on the downstream side), the broad-crested weir no longer performs as designed. At this critical degree of submergence, generally accepted to be about 70%, the upstream stage (head) over the weir begins to rise disproportionately to the discharge and the stage sensor detects an elevated stage for a given flow rate. Therefore, the monitoring station instrumentation calculates a higher flow rate than is actually occurring.

In 1988, hydrologists from the University of Tennessee and the Environmental Sciences Division (ESD) Watershed Hydrology Group conducted a series of backwater profile simulations using the Hydrologic Engineering Center's (HEC's) HEC-2 Water Surface Profiles model (U.S. Army Corps of Engineers 1982) on the MB monitoring station. Their goal was to characterize the submergence problem and to determine if tailwater channel improvements could be made to correct the problem. High water marks were available from a number of storm events and several stream cross-sections were surveyed for model input. Two scenarios were modeled: (1) existing channel conditions, as of 1988; and (2) improved channel conditions based on a theoretical trapezoidal cross section. The improved channel condition was limited by a concrete transfer line which crosses under the channel approximately 30 m (100 ft) downstream from the broad-crested weir. Figure 2 shows the results of this modeling effort. Under the conditions existing in 1988, the broad-crested weir would become submerged (greater than 70%) at approximately 75 cfs. For the improved channel conditions, the weir would become submerged and no longer operate as designed at approximately 125 cfs. The broad-crested weir (high-flow) control at MB was designed for a capacity of over 600 cfs. Therefore, even with tailwater channel improvement and maintenance, the broad-crested weir will become submerged at high flows and fail to operate properly.

A theoretical rating has been developed at the MB monitoring station that uses the low-flow control with an extended rating for stages above the wall containing the sharp-crested weir. The method used for developing this extended rating is consistent with that used by the USGS in the past. The ESD Watershed Hydrology Group uses this extended rating to calculate flows at the MB monitoring station for flows which exceed the capacity of the low-flow weir (34.7 cfs). Figure 3 shows the comparison of discharge measurements for two storms in May 1990. The standard rating overestimated the peak hourly flow rate for a major storm on May 1 by nearly 200%. For the smaller storm of May 4, the degree of overestimation is less, but still very significant. Although the two methods of discharge calculation give comparable results at flows below approximately 50 cfs, the degree of error increases with increasing discharge.

ORNL DWG 91-14919

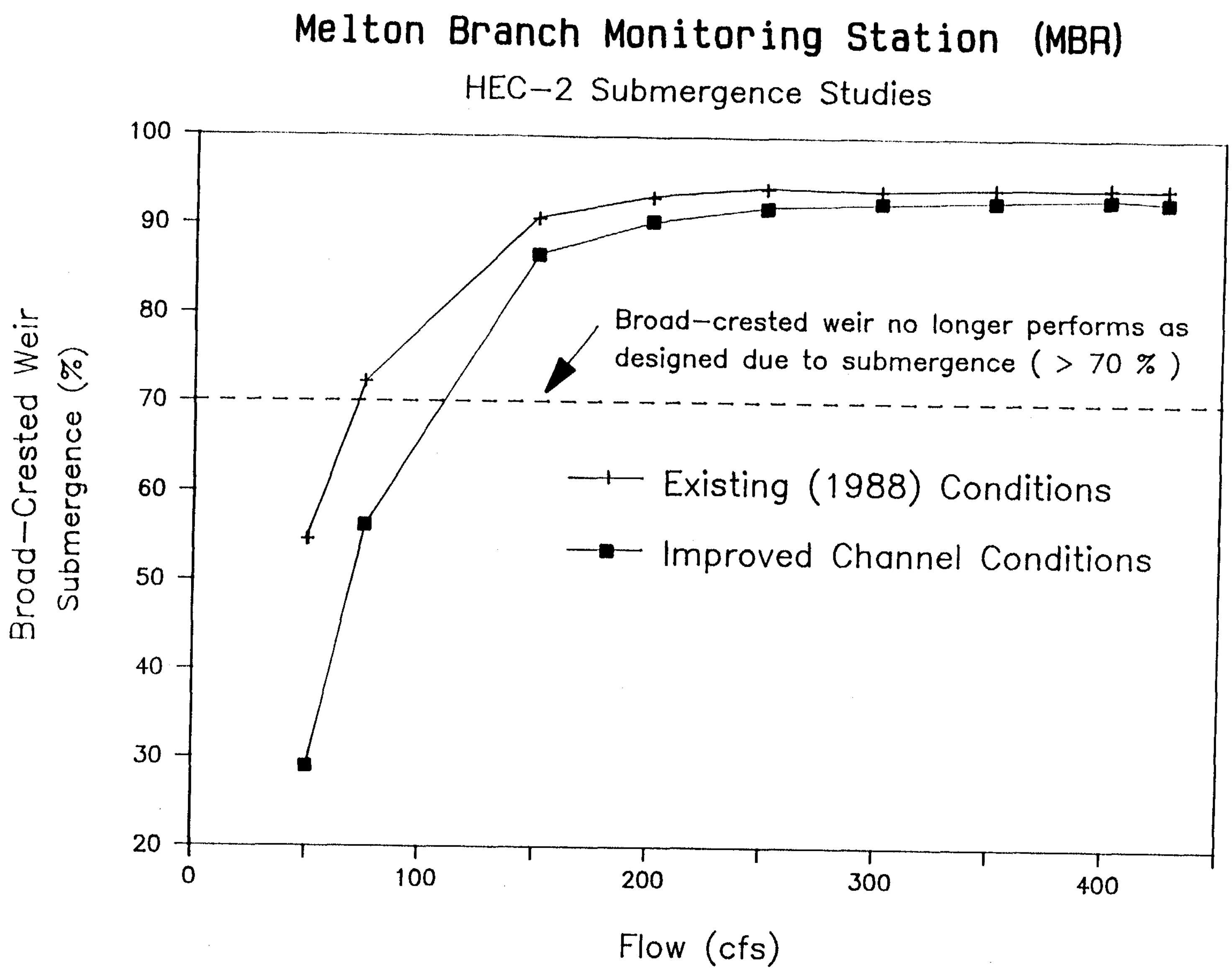

Fig. 2. HEC-2 submergence modeling studies, based on existing 1988 conditions, at the Melton Branch (MBR) monitoring station.

ORNL DWG 91-14922

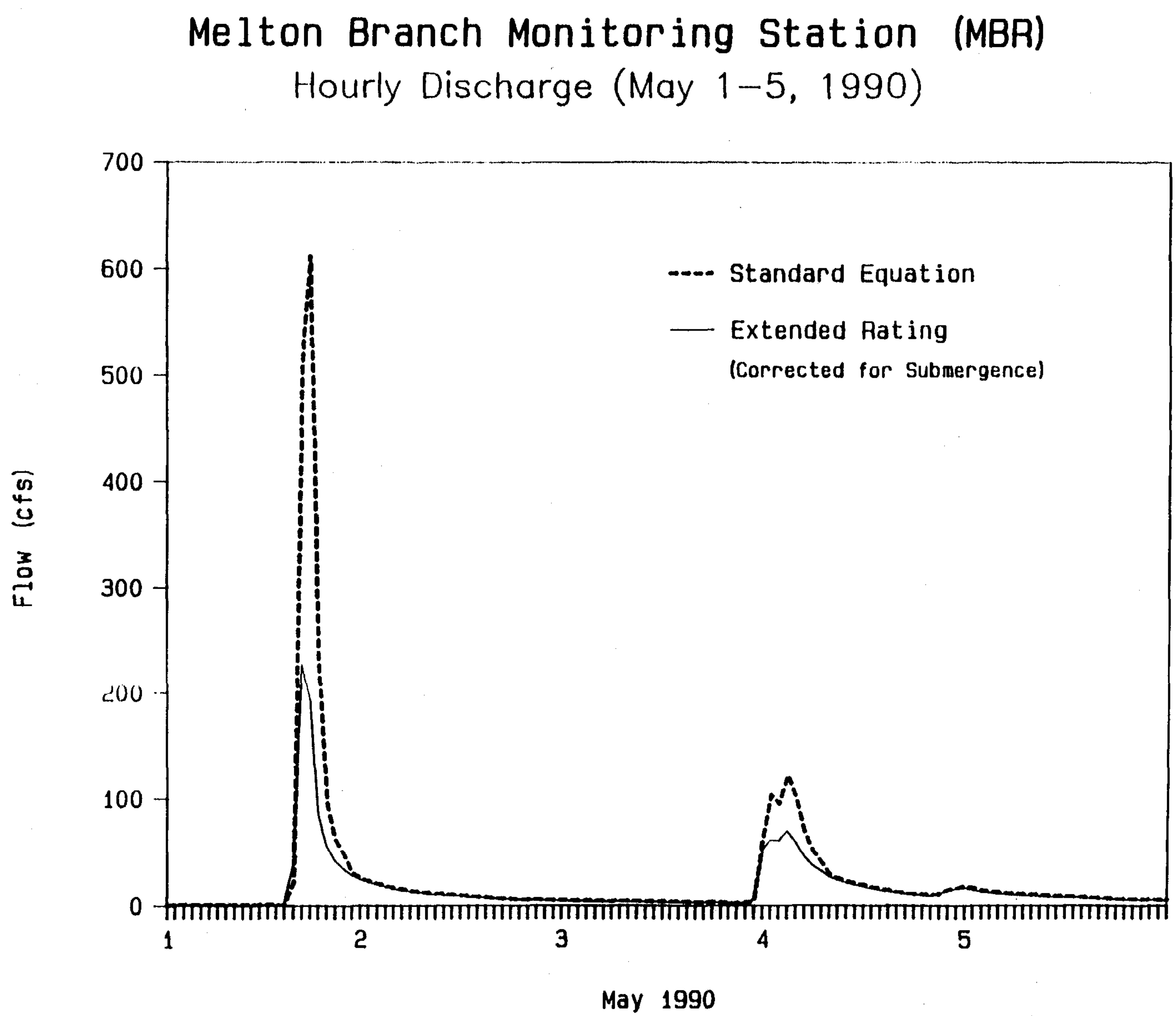

Fig. 3. Comparison of hourly discharge at Melton Branch (MBR) monitoring station for two storms occurring May 1 and May 4, 1990.

The high-flow measurement control devices on WOC and MB will be field-rated by U.S. Geological Survey (USGS) Water Resources Division staff for verification and development of stage-discharge relationships beginning in FY 1992. In-stream discharge measurements will be collected over a two-year period. The resulting relationships will be incorporated into the data processing procedures for discharge calculations. The USGS will evaluate methods for rating the high-flow control at WOD and will submit a proposal in FY 1992. Field rating of the high-flow control at WOD could begin as early as FY 1993.

The accuracy of discharge measurements at surface water monitoring stations in the WOC watershed is being degraded due to deposition of sediment and debris during high flow events resulting from heavy rainfalls. Flow measurement devices (i.e., weirs and flumes), stilling well intakes, and approach and tailwater sections in stream channels are being fouled by fine sediments, sand, rock and organic material (leaves, logs, etc.). In addition, during the growing season, aquatic plants flourish in and around these areas, often obstructing flow and further deteriorating the quality of discharge measurements. A complicating factor which must be considered in any mitigative effort is the presence of contaminants in the sediments. At the primary monitoring stations on WOC and particularly on MB, these contaminated sediments have essentially filled the stilling pool. There is a critical need to remove the contaminated sediments that are clogging stilling pools and gages above weirs.

Routine maintenance is necessary at all hydraulic control structures in order to collect accurate discharge measurements. A routine maintenance program has been developed in cooperation with ESP, and an Internal Environmental Assessment (IEA) has been initiated for National Environmental Policy Act (NEPA) compliance. This maintenance program will alleviate certain aspects of the sediment problem; however, in order to restore adequate conditions for accurate flow measurement at surface water monitoring stations in the WOC system, the geometry of approach and tailwater channels must be restored and maintained. Contaminated sediments can be removed only by the cooperative effort of the aforementioned groups and the development of a comprehensive program to deal with sediments at every level. This includes source, channel, and site maintenance components.

Personnel from the ESD, ESP (Compliance Group), Project Management, and EBASCO, Inc. (a Martin Marietta Energy Systems, Inc. (MMES) subcontractor) are developing a plan to remove contaminated sediments from behind weirs at the major monitoring stations on the Whiteoak Creek watershed. EBASCO has been commissioned by ESP to study methods and estimate cost for removing these contaminated sediments. They will address the problems caused by sediment deposition and the requirements for flow monitoring. EBASCO has agreed to present alternatives (e.g., partial removal of deposited sediments and removal of vegetation) for mitigating the immediate problem as well as alternatives (e.g., land management and maintenance programs) for controlling future erosion and deposition. They will also estimate the cost of alternatives.

1.2.2.4 Ad hoc committee on weir upgrades

Four surface water monitoring stations on small tributaries to WOC were recently identified for upgrading. The existing Homogenous Reactor Test (HRT) monitoring station, East Seep, West Seep and the Northwest Tributary (NWT) stations will be instrumented for stage-height measurement and flow-proportional sampling. A General Plant Project (GPP) was initiated to install new or upgrade existing monitoring systems at the four sites. Engineering plans for the upgrades at three of the sites were produced, but subsequent review of the designs suggested that performance objectives should be developed that are more technically defensible.

The adequacy of surface water flow and water quality data rests intrinsically with selection of the most appropriate hydraulic control structure for the particular site of concern. Regulatory guidance emphasizes accurate flow rate measurements because they are basic to calculating water budgets and mass fluxes of water-borne contaminants. A sound decision on the selection of the hydraulic control structure will allow water quality sampling equipment to function as designed. Therefore, this guidance on decision making for flow measurement structures is a key element of an effective surface water monitoring program.

A primary issue that requires resolution is whether the weirs presently in place at these monitoring sites should be replaced with weirs of new design or with flumes. In general, flumes allow sediment transported from upstream to pass more readily through the flow control structure (flume) than do weirs, thereby reducing the need to maintain the approach section or the stilling pool. However, the initial cost of installing flumes may be greater than the cost of installing weirs. Sediments at some of the sites are contaminated with radionuclides; therefore, removing the sediment may represent a health risk to workers as well as a disposal problem. Because a very large proportion of the sediments are expected to deposit in WOL, which is restricted from public access and is already contaminated, the movement of sediments downstream from these structures will have negligible effect.

The objectives of the Ad Hoc Committee on Weir Upgrades are:

1. evaluate proposed design alternatives for streamflow monitoring stations for small tributaries at ORNL;

2. document performance criteria for the upgrades as they relate to the flow control structure, which includes the approach section/stilling pool;

3. provide a data package for engineering design so that costs of alternative designs can be evaluated; and

4. outline follow-on work that must be addressed to facilitate surface water monitoring station upgrades in the future.

Performance criteria will be chosen consistent with the overall programmatic objectives. These sites are not part of the compliance monitoring program, with one exception: the West Seep, which is identified in the WAG 6 Groundwater Surveillance Plan (ORNL 1991) for continuous flow measurement and flow-proportionate water-quality sampling, is included in the compliance monitoring program.

This plan is just beginning to be implemented. However, these stations are critically important to the ERP. The ERP has five monitoring goals for this project:

(1) provide baseline data on contaminant flux levels in surface waters and groundwater,

(2) assess the performance of remediated sites and ICMs,

(3) provide information needed in assessment/risk modeling,

(4) identify large-scale and long-term trends in environmental quality, and

(5) provide necessary understanding of groundwater and surface water systems by combining information with that gathered in the Site Investigation Special Studies.

Whereas the emphasis for most compliance monitoring is to document and compare contaminant concentrations relative to concentration limits set forth in regulations, for ER the important information is contaminant flux, typically quantified over a period of 12 months. An appropriate measure of success for remedial actions is the reduction of this annual flux measured at key points in the hydrologic system. Measurement of the long-term contaminant flux is important because an increase in it leads to the assessment of potential health risks to individuals downstream of the Laboratory.

To generate a record of the annual flux, it is necessary to have complete and accurate flow measurements and flow-proportionate water quality samples. In some instances where contaminant concentrations are correlated to flow, it is possible to intensively sample water during storms and use these data, together with a correlation model and the annual streamflow hydrograph, to estimate annual fluxes. In all cases, reliable flow data are needed throughout the entire year.

A flow duration analysis indicates the magnitude and frequency of flows expected and should therefore be designed for. For West Seep, approximately two years of continuous hourly discharge data are available for analysis. Figure 4 shows the flow duration curve (flow vs frequency) for the West Seep station for this limited data set. The data shows that discharge was between 0.1 and 1.0 cfs approximately 50% of the time, with discharge seldom falling below 0.01 cfs and seldom exceeding 10 cfs. This period of record is not enough to analyze frequency to accurately determine the discharge associated with infrequent return periods. However, the data should be fairly adequate to bracket the 95th percentile. That is, discharge at West Seep is between 0.02 and 4.0 cfs approximately 95% of the time. However, volumetrically, 95% of the flow occurs between 0.1 and 30 cfs. This is because a disproportionately high percentage of total flow passes a point on a stream during a few major storms, whereas a small percentage of total flow passes under normal flow conditions. This emphasizes the need to consider the discharge volumetrically because the percentage of contaminants passing a point in a stream would more closely parallel flow volume.

The West Seep monitoring station was given the highest priority because this tributary drains WAGs 6 and 7, which are presently in the RI stages of the ERP. Therefore, the initial investigation for station upgrade was targeted for this site. The objective was to evaluate the existing flow measurement device for adequacy and compare it to a number of alternative designs (flumes, etc.) for replacement. The guidelines for adequacy included the capability to measure the 95th percentile (volumetrically) with an accuracy of $\pm10\%$ and to measure all other flows (up to the 25-year peak) with an accuracy of $\pm25\%$.

ORNL DWG 91-14924

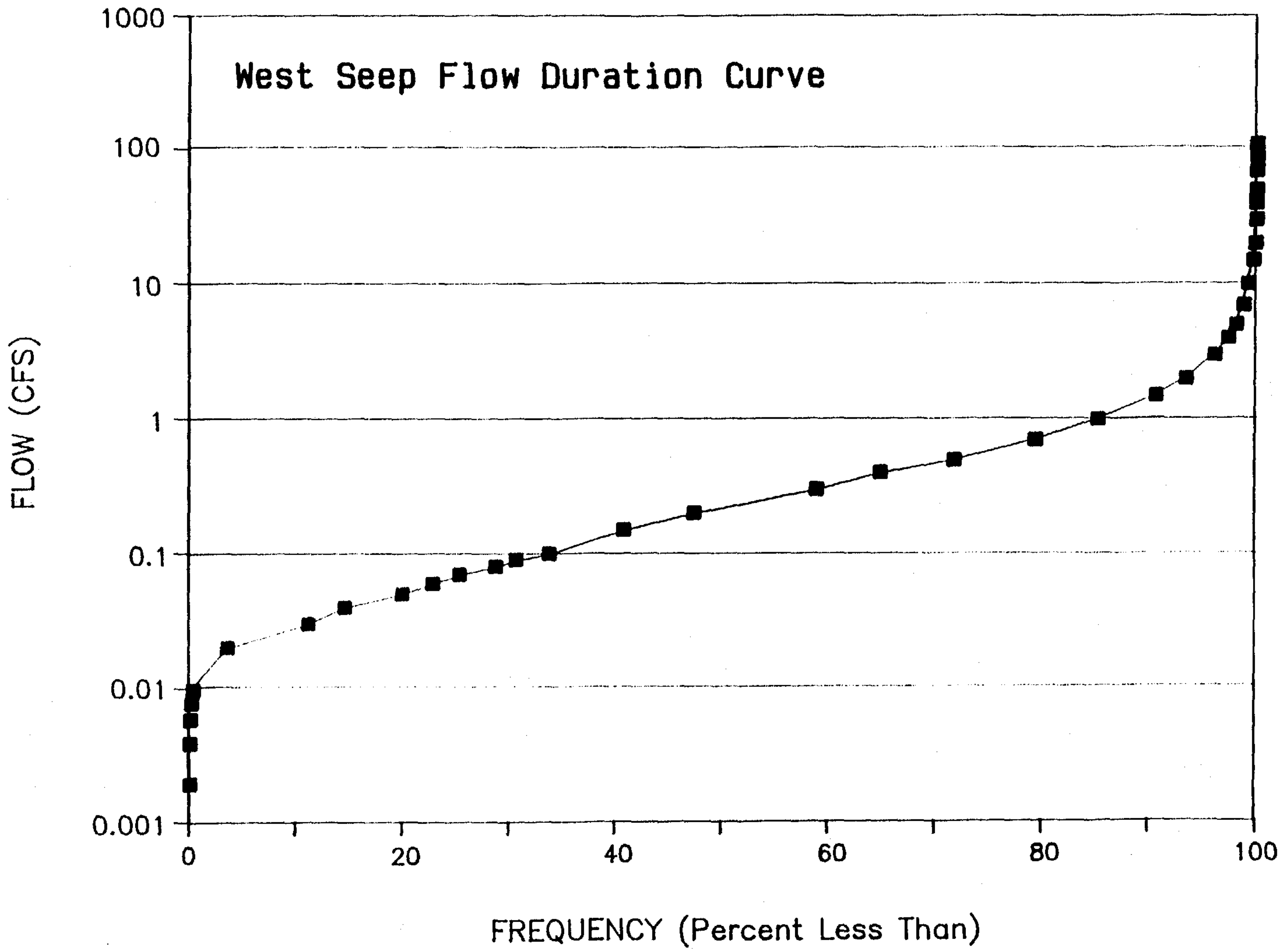

Fig. 4. Flow duration curve (flow vs frequency) for the West Seep station, based on two years of hourly discharge data.

The Soil Conservation Service (SCS) TP-49 flood hydrograph model was used to estimate the peak runoff associated with a 25-year storm on the West Seep drainage. The 25-year peak flow calculated by the SCS model was approximately 90 cfs. The maximum capacity of the existing weir is approximately 33 cfs. Therefore, it will be impossible to measure flows up to the 25-year peak with a high degree of accuracy, although flows above 33 cfs could be estimated by a number of methods.

The HEC-2 Water Surface Profiles model was used to simulate backwater profiles on the West Seep weir to evaluate the effects of tailwater conditions on submergence and subsequent reduction in flow during high-flow events. Stream cross-sections were surveyed at six locations at, and downstream from, the weir plate. A single calibration point (upstream and downstream water levels) was obtained during a condition of high flow about two weeks before the surveys. Model results (Fig. 5) indicate that, under existing conditions, the weir becomes partially submerged at approximately 10 cfs and that with a moderate improvement to the tailwater channel, the weir becomes partially submerged at approximately 22 cfs. Unlike broad-crested weirs, sharp-crested weirs (theoretically) suffer some degradation in accuracy of flow measurements for minor degrees of submergence. However, Fig. 6 indicates that the degree of reduction in flow is relatively minor for the two conditions simulated. Under existing conditions, the error caused by submergence of the weir is about 3–4%.

As a part of this ongoing project, similar analyses have been performed on a number of alternative designs. However, no final decision has been made on the selection of a flow control device to replace the existing structure. Cost estimates must be performed for each alternative, and these necessarily include the costs of excavation and disposal of potentially contaminated sediments (see Station Upgrade and Maintenance section). The evaluation of this and three other small monitoring stations will continue into FY 1992.

1.2.2.5 Transport of contaminants during storms

The objective of this study was to quantify the release of subsurface contaminants to streams in and around ORNL waste management areas. Solomon et al. (1991) describe the transport of contaminants from solid waste storage area (SWSA) 5 during storms along two principle pathways: (1) the saturated groundwater system, and (2) the intermittently saturated stormflow system. Specific objectives of the study are:

1. to develop rating curves of concentration (of radionuclides) vs stream discharge in order to accurately measure the total contaminant discharge in streams over time; and

2. to quantify the ratio of contaminants released slowly (with groundwater discharge or base flow) to that released rapidly during storm events (with storm flow or quick-flow).

In the winter and spring of 1988, a time series of stream samples was collected during three storms on WOC and MB near the primary surface water monitoring stations above their confluence. The collected samples were analyzed for radionuclides and trace metals; radionuclides included ^{3}H, ^{90}Sr, ^{137}Cs, and ^{60}Co. These four contaminants concentrations as functions of stream discharge during the three storms were reported by Solomon et al. (1991). The concentration vs discharge relationship for ^{137}Cs and ^{60}Co, on the other hand, is a function of suspended sediment transport and thus does not parallel the ^{3}H and ^{90}Sr results.

ORNL DWG 91-14921

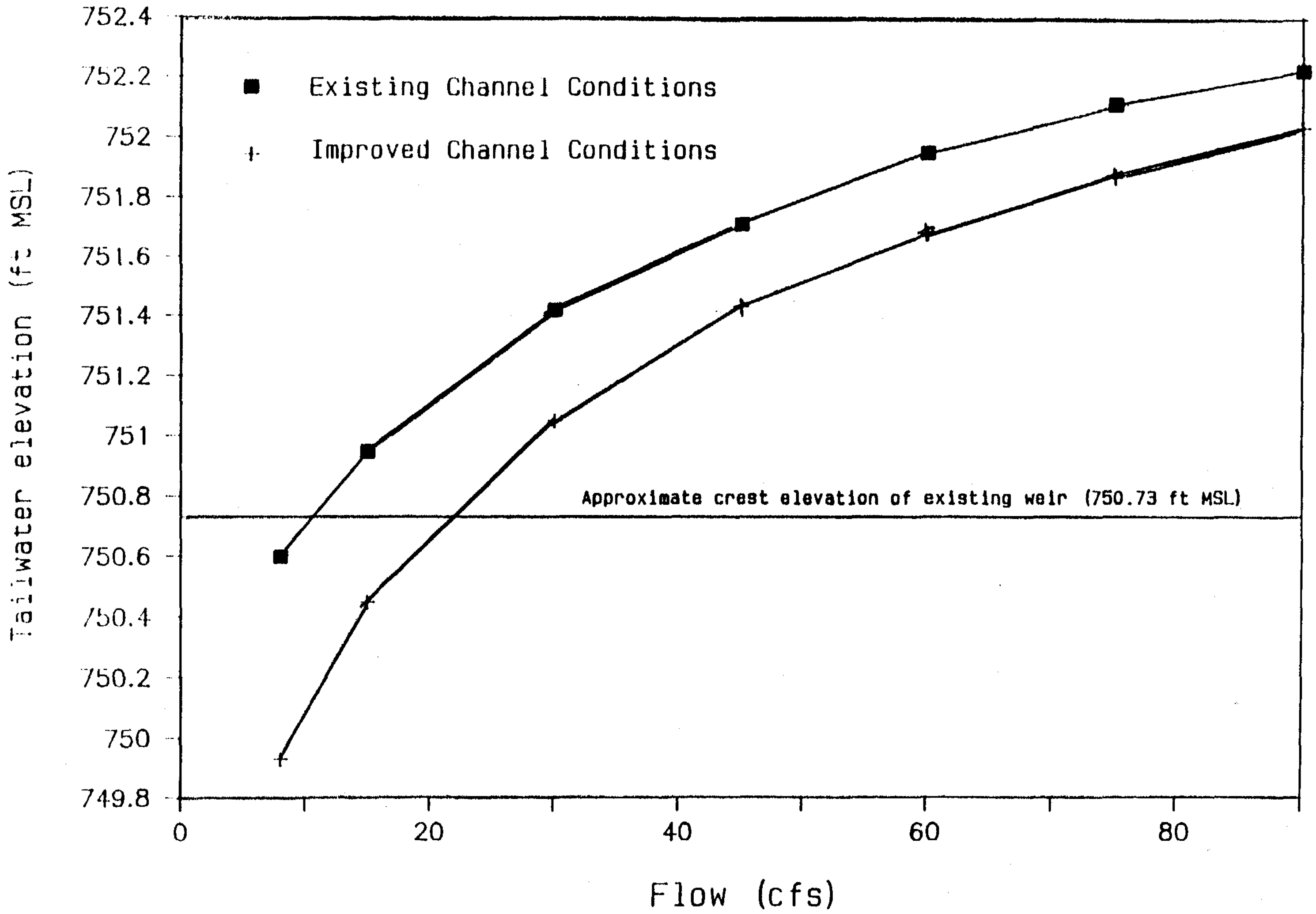

Fig. 5. Backwater profiles at the West Seep monitoring station, using the HEC-2 model.

ORNL DWG 91-14918

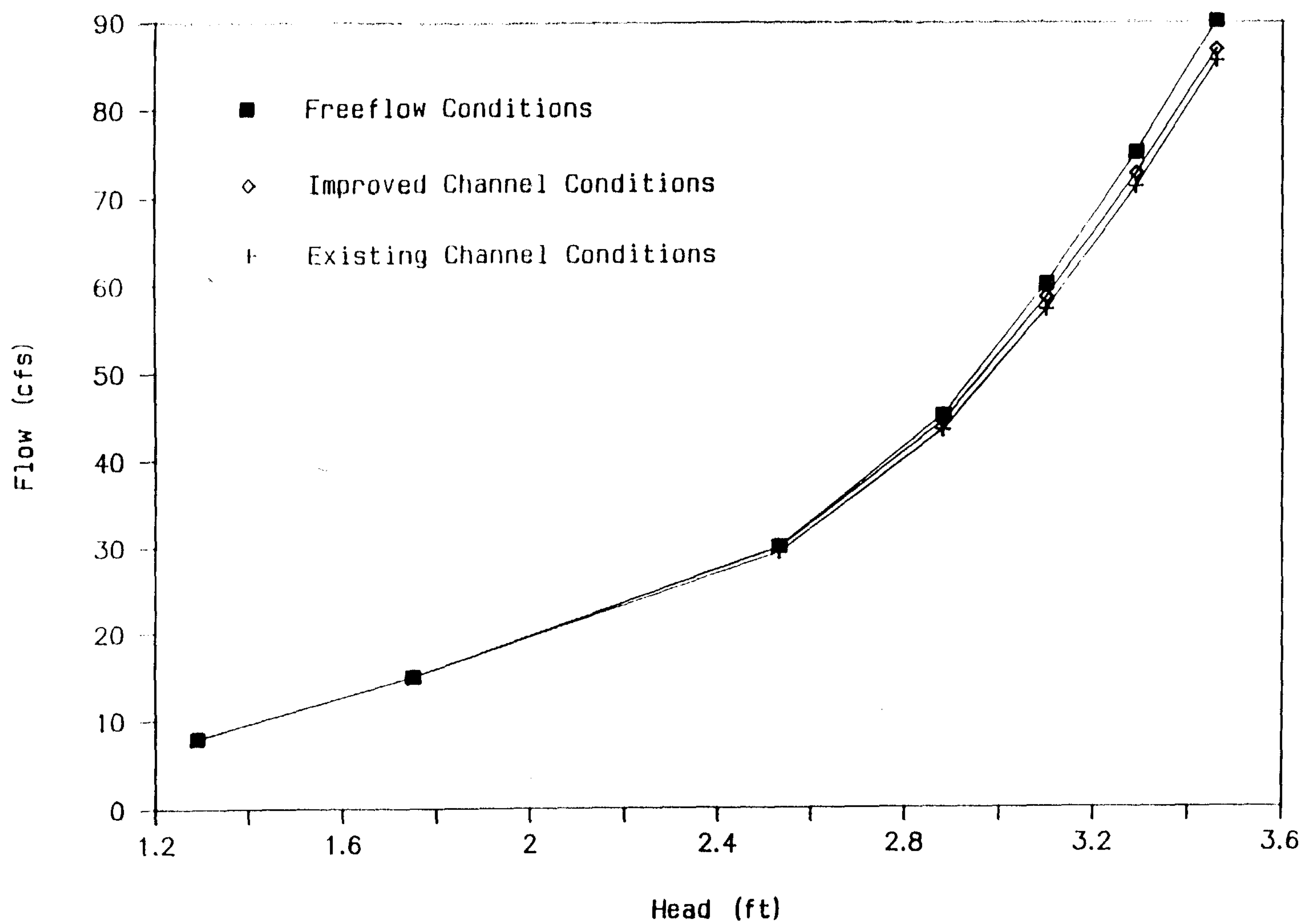

Fig. 6. Backwater profiles at the West Seep monitoring station using the HEC-2 model, under existing sharp-crested weir flow conditions.

In general, the ^3H mass flow and ^{90}Sr mass flow increases as discharge increases during storms. The relationships between concentration and discharge for ^3H and ^{90}Sr in MB show good correlation for each; therefore, it is possible to describe the concentrations as functions of discharge for MB (Solomon et al. 1991). However, the relationship between concentration and discharge for WOC is not well correlated for either radionuclide because the main plant area releases contaminants randomly. Therefore, it is not possible to describe the concentration as a function of discharge for WOC.

Although stream discharge is greater (2–6 times for stormflows sampled during this study), the total ^3H release in WOC is 2–10 times less than in MB. This reflects the substantial release of ^3H from SWSA 5 into MB. The total ^{90}Sr release is greater in WOC by about a factor of two. A significant portion of this ^{90}Sr is probably discharging from the main plant area via First Creek and from SWSA 4. An exponential relationship between concentration and discharge is apparent for both ^3H and ^{90}Sr at both WOC and MB (monitoring stations). At low flows, streamflow is made up primarily of groundwater discharge. During storms, significant dilution occurs as less-contaminated water enters the stream. However, at a critical discharge value, the amount of dilution slows down in relation to the amount of increase in discharge and concentrations remain relatively constant with increasing discharge. As a result, the actual mass of both ^3H and ^{90}Sr being transported in WOC and MB shows a dramatic rise during periods of high flow. The increase of contaminant flux during storms indicates an increase in subsurface contaminant discharge is occurring. Solomon (1991) used graphical hydrograph separation and modeling to estimate that 16% of the ^3H and 27% of the ^{90}Sr release in MB during 1988 occurred as quick-flow.

This study has a number of implications for future remedial actions. Results indicate that any remedial actions must be directed toward the groundwater and shallow subsurface water systems. In addition, the short-term effectiveness of remedial actions aimed at reducing the contaminant source depends on the mass of contaminant stored in the porous media (secondary source term) outside the primary source. If the secondary source term is small, remedial actions applied to the primary source would reduce releases to streams in the near-term. However, if the secondary source term is large, then remedial actions that reduce the discharge of water must be used to improve near-term results.

1.2.3 WAG 2 Remedial Investigation

The ORNL WAG 2 is located in the WOC drainage downstream of ORNL discharge points and includes the associated floodplain and subsurface environments of WOL, WOC, MB, and their major tributaries, and the WOCE of the Clinch River/Watts Bar system. In addition, WAG 2 is downgradient from numerous contaminated areas (WAGs) in the WOC watershed. WAG 2 is unique in that essentially all contaminants residing in, and therefore being released from WAG 2, came from these upgradient WAGs. RIs are underway or planned for these WAGs; therefore, contaminant inputs to WAG 2 will change as individual upgradient areas are remediated. For this reason, WAG 2 will be remediated only after the upgradient WAGs have been remediated. However, because the WOC system acts as a conduit and a sink for contaminants from upgradient areas, the WAG 2 RI is already commencing.

Because hydrologic fluxes through WAG 2 link contaminant sources in the WOC watershed with off-site areas, a quantitative understanding of where contaminants enter WAG 2 is needed. In addition, an inventory of contaminants in the system and the transport mechanisms that move them into, through, and out of the system are needed in order to characterize the temporal and spatial mass balance of contaminants in WAG 2. Since such information does not currently exist nor is it likely to become available through efforts in other WAGs, the WAG 2 RI Plan (1990) will address the need to (1) take immediate steps to protect the public and the environment, (2) monitor contaminant releases from ORNL WAGs, and (3) form a foundation for eventual remedial actions in WAG 2. The RI Plan calls for a phased effort to characterize, monitor, assess risk, and identify remedial needs and alternatives.

The WAG 2 RI Plan (1990) is structured with a short-term component to be conducted while upgradient WAGs are investigated and remediated, and a long-term component that will complete the RI process when upgradient WAGs have been remediated. The interim-period plan has two objectives:

1. make preliminary surveys and take samples to determine hot spots (discrete areas of significant contamination that may need ICMs to protect the public or the environment), identify areas where additional data are needed, fill data gaps for the first round of risk assessment, and clearly delineate the boundary of WAG 2; and

2. use a multimedia environmental monitoring and characterization program to (a) define and monitor the input of contaminants from adjacent WAGs, (b) characterize the hydrology of the WOC system and support a mass-balance approach to determining sources, sinks, and transport of contaminants in WAG 2, and (c) establish the basis for determining long-term trends in contaminant levels.

Long-term objectives of the WAG 2 RI include:

1. define the nature and extent of contamination in WAG 2;

2. quantify any risk to human health and the environment resulting from contamination; and

3. make preliminary evaluations of potential corrective measures and remedial action alternatives for the operable units in WAG 2.

Monitoring and sampling efforts will be designed according to the results of risk assessments, which ultimately determine the need for corrective measures to reduce risks. This risk-driven monitoring and sampling will proceed while adjacent WAGs are being remediated. The monitoring program and preliminary risk analysis will be conducted on a reach-by-reach basis. Monitoring will support a mass-balance approach for determining contaminant transport and inventories. This approach mirrors the identification of operable units (or reaches) to be considered for corrective measures or eliminated from further efforts.

Work to be conducted in the initial stages of the WAG 2 RI includes: (1) continued synthesis of existing information and preliminary contaminant screening; (2) formulation and implementation of the initial sampling and analysis plan; (3) sampling of areas (e.g., new groundwater wells and floodplain soils) for which no data are available, and which are suspected to be contaminated, to identify hot spots and operable units, (4) upgrade of discharge monitoring facilities (see Station Upgrades and Maintenance section) to improve the hydrologic budget and to identify contaminant inputs; and (5) surveys of WOC sediments and floodplain soils, work on sediment transport models, and sampling of WOL bottom sediments.

All efforts on WAG 2 will be coordinated with upgradient WAGs, the Clinch River RFI, existing monitoring programs, the Technical Integration Committee, and the ERP. Remedial investigations in adjacent WAGs will provide short-term information on contaminant releases and potential releases, based on inventory records, from those WAGs. All data will be available from the Data and Information Management System (DIMS) consolidated data base as required by the Federal Facility Agreement (FFA)[under Sect. 120 of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) and Sect. 6001 of RCRA] between DOE, the U.S. Environmental Protection Agency (EPA) Region IV, and the Tennessee Department of Health and Environment (TDHE).

The WAG 2 RI Plan (1990) provides a brief history of the site, a characterization of the environmental setting, descriptions of the existing monitoring programs at ORNL and in the WOC system that contribute to WAG 2, existing information for contaminant inputs into the WOC system, and information for contaminants in and contaminant releases from WAG 2.

1.2.4 Other WAGS and Contaminant Releases

The RFA identified all sites, grouped into 20 WAGs on the basis of hydrogeological and functional parameters based on proximity, considered to be potential RCRA 3004(u) SWMUs. With the possible exception of the WOCE below WOD, contamination in the WOC system is a result of releases from active and inactive waste sites in 11 WAGs located within the WOC watershed.

Information available on known releases from WAGs into the WOC/WOL drainage is highly variable from one WAG to another. There is not enough data to fully characterize either the historical or continuing releases from any WAG. Table 1 summarizes primary sources of data and contaminants released for each WAG. These existing reports typically provide information on waste inventories within the WAG, limited data on known releases, and results of various characterization studies. Although available information does not allow releases from each WAG to be fully characterized, the waste inventory and known release data can be used to identify key radioisotopes and, to a lesser extent, elements that may potentially be released from a WAG (Table 1). Data on organic contamination is limited to a very few sites. This summary of key potential contaminants can be used to guide further monitoring and characterization efforts.

This section briefly describes each of the 11 WAGs which are located at least partially within the WOC watershed, and provides existing data on releases from each. It also summarizes available information about contaminant releases, both historical and continuing, from each WAG (except WAG 2) in the WOC watershed. It provides information from a

Table 1. Sources of data and contaminants known or suspected to have been released from WAGs in the Whiteoak Watershed

WAG	NAME	CONTAMINANTS[a]	DATA PACKAGE[b]	RI/RFI PLAN[c]
1	ORNL Main Plant Area	^{60}Co, ^{90}Sr, ^{137}Cs, ^{15X}Eu, ^{232}Th, ^{23X}U, ^{23X}Pu, ^{241}Am, ^{244}Cm, other radionuclides, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Zn, TRE, PCBs, Chlorodane	W. J. Boegly et al. 1987	BNI
3	Solid Waste Storage Area 3	^{3}H, ^{90}Sr, ^{137}Cs, TRE	R. R. Shoun 1987	BNI
4	Solid Waste Storage Area 4	^{3}H, ^{60}Co, ^{90}Sr, ^{106}Ru, ^{137}Cs, ^{23X}Pu, other radionuclides, TRE	E. C. Davis & R. R. Shoun 1986	BNI
5	Solid Waste Storage Area 5	^{3}H, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{233}U, ^{23X}Pu, ^{241}Am, ^{244}Cm, other radionuclides, Cr, Hg, Ni, Pb, Zn, PCBs	R. R. Shoun 1987	BNI
6	Solid Waste Storage Area 6	^{3}H, ^{14}C, ^{60}Co, ^{137}Cs, ^{15X}Eu, ^{23X}U, Cr, Cu, Hg, Mo, Ni, Pb, Zn, VOCs, nitrates	W. J. Boegly et al. 1984	BNI
7	LLW Pits & Trenches Area	^{3}H, ^{60}Co, ^{90}Sr, ^{99}Tc, ^{106}Ru, ^{137}Cs, ^{233}U, Cr, Ni, Zn, nitrates	B. P. Spalding 1987	BNI
8	Melton Valley Area	^{60}Co, ^{90}Sr, ^{137}Cs, Cr, Cu, Zn	W. J. Boegly & A. F. Iglar 1987	BNI
9	Homogeneous Reactor Experiment (HRE) Area	^{60}Co, ^{90}Sr, ^{137}Cs, Cr, Zn	R. G. Stanfield & C. W. Francis 1986	BNI
10	Hydrofracture Injection Wells & Grout Sheets	^{90}Sr, ^{137}Cs, ^{244}Cm, TRU isotopes		BNI
13	Environmental Research Areas	^{137}Cs	W. J. Bogley & G. K. Moore 1988	
17	ORNL Services Area	^{137}Cs, Cd, Cr, Cu, Zn, fuel-derived hydrocarbons, & solvents	W. J. Boegly & G. K. Moore 1988	BNI

[a]Based primarily on data in ORNL RCRA Facility Investigation (unpublished) and environmental data packages for each WAG. ^{106}Ru and TRE have short half-lives (e.g. ~1 year) and should have decayed to trivial levels by this time.
[b]Includes site characterization report for some WAGs where no environmental data package was prepared.
[c]RI=Remedial Investigation; RFI=RCRA Facility Investigation; BNI=Bechtel National, Inc.

number of sources (WAG 2 RI Plan 1990) detailing additional data needs for adequate characterization of the sources (historical and continuing) of contamination to the WOC/WOL system. Further information will be obtained through programmatic linkages with ongoing and planned RI/FS activities in these WAGs and through further review of existing monitoring and characterization data.

WAG 1

Description: WAG 1 is the ORNL main plant area, which includes all the operating research and development facilities within the main security fence at ORNL. Historically, ORNL has developed and tested various reactor concepts, developed and operated fuel reprocessing technologies, produced radioactive and stable isotopes on a large-scale, and managed wastes from these activities. These activities have been focused primarily in WAG 1, although several other WAGs have also been involved. WAG 1 consists of 99 sites currently considered to be SWMUs, including radioactive waste collection pipelines and tanks, solid waste storage areas, waste treatment facilities and impoundments, leak and spill sites, and miscellaneous waste handling and storage units. WAG 1 drains into WOC directly, through storm drains, and through two small tributaries, First Creek and Fifth Creek, which flow through WAG 1 approximately from north to south (ORNL grid). Conceptual modeling studies have demonstrated the potential for rapid transport of contaminants along the massive array of subsurface pipeline trenches directly to WOC and its WAG 1 tributaries.

Releases: Virtually every radionuclide, chemical, and organic compound ever used at ORNL can be found in WAG 1. And, because all drainage and treated effluents from WAG 1 ultimately discharge to WOC, the significant amount of historical release data available indicate that WAG 1 was a major source for radionuclide, heavy metal, and chemical waste releases to WOC. Analysis of the 1989 Environmental Monitoring Report for the Oak Ridge Reservation (Energy Systems 1990) suggests that WAG 1 is still the primary source of ^{60}Co, ^{137}Cs, and ^{90}Sr to the WOC/WOL system. Recent biological monitoring data has detected PCBs and chlordane in the reach of WOC affected by WAG 1 (Loar 1990). Sample data also indicate measurable levels of a suite of metals including Cr, Cu, Mo, and Zn. An ongoing remedial investigation of WAG 1 is expected to yield data on groundwater contamination and release rates to WOC. Existing surface water monitoring programs provide periodic data on continuing releases of selected radioisotopes from WAG 1. Additional monitoring data are needed, however, to determine the level of continuing releases, if any, of the entire suite of contaminants indicated in Table 1.

WAG 3

Description: WAG 3 consists of three SWMUs including SWSA 3, the closed scrap metal area, and the current operating contractors' landfill. This WAG is located in Bethel Valley about 1 km (0.6 mi) west of the west entrance to the ORNL main plant area. SWSA 3 and the closed scrap metal area are inactive landfills containing radioactive solid wastes and surplus materials generated at ORNL between 1946 and 1979. The contractors' landfill was opened in 1975 and is used to dispose of various uncontaminated construction materials and fly ash from the ORNL steam plant. WAG 3 drains into the NWT of WOC. The NWT enters WOC downstream from the main plant area and could contaminate the lower reach of WOC within WAG 1 and ultimately the lower reaches of WOC and WOL (WAG 2), and the Clinch River.

Releases: There are no reliable records of what was disposed of in SWSA 3, because fire destroyed the records in 1961. Sketches and drawings indicate that alpha and beta-gamma wastes were buried in separate areas or trenches. Some of the alpha wastes may have been placed in drums and buried in concrete-lined trenches, and some were probably placed in unlined trenches. Hazardous chemical wastes are also likely to have been buried in SWSA 3. Characterization data suggest that SWSA 3 has historically been a source of ^{90}Sr, and samples of surface soils and gravel in the Contractors Landfill area of WAG 3 revealed ^{90}Sr and ^{137}Cs with ^{60}Co at or near detection levels. Recent monitoring data (Energy Systems 1990) and historical studies (Stueber et al. 1981) suggest that WAG 3 contributes small quantities of ^{90}Sr and ^{137}Cs to the NWT. However, no data are available on heavy metal or organic contamination. Additional monitoring and characterization data will be required to determine whether WAG 3 is (or has been) a source of contaminants other than ^{90}Sr and ^{137}Cs.

WAG 4

Description: WAG 4, located southwest of the ORNL main plant area, consists of three SWMUs including the low-level waste (LLW) line north of Lagoon Road, pilot pits 1 and 2, and SWSA 4. From 1954 to 1975, liquid radioactive wastes were transferred to the waste pits and trenches (WAG 7) through the LLW line north of Lagoon Road. Two known leak sites were covered with bentonite and asphalt caps in 1983. The pilot pit area (Building 7811) was constructed in late 1955 for use in pilot-scale studies of radioactive waste disposal. Currently, all that remain at the site are three large concrete cylinders embedded in the ground, a control building used to store field and laboratory equipment, and four large concrete cylinders used in a municipal waste leaching experiment. SWSA 4, which covers 9.3 ha (23 acres), was opened for routine solid waste burials from 1951 through 1959, but remained open as a disposal area for uncontaminated fill until 1973. Waste from sources outside ORNL accounts for about half of the volume of material buried in SWSA 4. WAG 4 drains to WOC directly and through an unnamed tributary on its southern boundary.

Releases: Records of the composition of radioactive solid waste disposed of in SWSA 4 during all but its last 2 years of operation were lost in a fire. In addition, over half of the waste buried in SWSA 4 came from sources outside ORNL. For these reasons, SWSA 4 must be considered a potential source for a wide range of radioisotopes including transuranics (Table 1). Characterization data have demonstrated that SWSA 4 is a major contributor of ^{90}Sr to the WOC/WOL system. Soil samples have also shown elevated levels of ^{60}Co and ^{137}Cs in SWSA 4. Stream gravel surveys have shown that SWSA 4 has been a source of these isotopes, as well as of copper, nickel, and zinc to WOC. Recent monitoring data (Energy Systems 1990) suggests that SWSA 4 is a major source of ^{90}Sr to the WOC/WOL system and is the largest contributor of ^{3}H to the reach of WOC above Melton Branch. No data are available on continuing elemental or organic contamination from WAG 4. Additional data will be required to determine whether and to what extent WAG 4 is a continuing source of heavy metals and organics.

WAG 5

Description: WAG 5 is approximately 2 km (1.2 mi) south of the main plant area in Melton Valley between WOC and MB, upgradient from their confluence. This WAG consists of 22 SWMUs in SWSA 5 and SWSA 5 North (Transuranium [TRU] Waste Storage Area), including two line leak sites, an old landfill, the 7835 process waste sludge basin, and the surface facilities constructed to support both Old and New Hydrofracture facilities (including several LLW storage tanks and two impoundments). Melton Branch separates the New Hydrofracture Facility from the remainder of WAG 5. SWSA 5, which covers 32.3 ha (80 acres), received radioactive wastes from 1959 through 1973. The area known as SWSA 5 North, which covers 4 ha (10 acres), has been used for retrievable storage of transuranic wastes since 1970. WAG 5 drains into WOC directly, into an unnamed tributary to WOC, into MB, and into an unnamed tributary to MB.

Releases: Approximately 200,000 Ci (curies) of LLW and TRU wastes are buried at SWSA 5. In addition, more than 62,000 Ci of TRU waste is retrievably stored in SWSA 5 North, much of it buried in concrete casks (Stewart et al. 1989). Eight 190,000-L stainless-steel tanks at the New Hydrofracture Facility (NHF) site hold concentrate from the LLW evaporator. The Old Hydrofracture Facility (OHF) pond contains contaminated water and sediments with almost 500 Ci of activity. The predominant isotopes in all the LLW facilities are ^{60}Co, ^{90}Sr, and ^{137}Cs. TRU wastes are primarily ^{244}Cm, with lesser amounts of several other isotopes. Some lead and mercury were also buried with the TRU wastes (Stewart et al. 1989). Four separate studies have identified radioactively contaminated groundwater around WAG 5 (ORNL 1987a, Ashwood et al. 1990b, Wickliff et al. 1990). Groundwater near the OHF pond is contaminated with ^{3}H and ^{90}Sr. Six wells and one seep around SWSA 5 were contaminated with ^{90}Sr, ^{137}Cs, and RCRA-regulated hazardous wastes (e.g., lead). Wells along the southern perimeter of SWSA 5 contained measurable levels of ^{90}Sr. One well in SWSA 5 North contained ^{244}Cm and ^{24X}Am, and another had elevated levels of ^{3}H. Stream gravel surveys suggest that SWSA 5 has been a source of ^{90}Sr, chromium, nickel, and zinc to Melton Branch. Stream water samples have shown elevated levels of ^{3}H north of SWSA 5 North (D. S. Wickliff, Oak Ridge National Laboratory, personal communication to D. M. Borders, University of Tennessee, August 1991). Recent monitoring data (Energy Systems 1990) suggest that WAGs 5 and 9 combined contribute about one third of the ^{90}Sr and more than half of the ^{3}H that enters WOC. It is not possible, with current monitoring data, to separate the contribution of WAG 5 from that of WAG 9. In addition, operational monitoring of SWSA 5 North has detected levels of ^{244}Cm and ^{241}Am in groundwater downgradient of the burial trenches (D. S. Wickliff, Oak Ridge National Laboratory, personal communication to D. M. Borders, University of Tennessee, August 1991). Additional data will be required to accurately assess past and continuing releases of radioisotopes, heavy metals, and organic compounds from WAG 5.

WAG 6

Description: WAG 6 consists of three SWMUs including SWSA 6, the Emergency Waste Basin (EWB), and the Explosives Detonation Trench (EDT). All three facilities are in Melton Valley, approximately 2 km (1.2 mi) southwest of the main plant area south of Lagoon Road and north of WOL. SWSA 6, which covers 28 ha (68 acres), is currently the only operating LLW disposal site at ORNL. Portions of this site have been closed under

RCRA regulations because of the disposal of RCRA-regulated waste after 1980. The EWB was constructed in 1961-1962 to provide storage if wastes could not be released from ORNL to WOC. However, there is no reported use of the basin for waste storage. The EDT was used to destroy explosive and shock-sensitive chemicals. A closure plan has been filed for the detonation trench. WAG 6 drains to WOL directly through four unnamed surface drainages and indirectly from its eastern hillslope to the West Seep tributary to WOL in WAG 7.

Releases: As the only operating LLW disposal site at ORNL, SWSA 6 continues to receive solid LLW for burial by improved confinement disposal technologies such as concrete silos, steel-lined auger holes, and concrete vaults on a concrete pad. Through the end of 1984, more than 250,000 Ci of LLW had been disposed of in SWSA 6. RCRA-regulated wastes (e.g., scintillation fluids, oils, cleaning solutions, alcohols, paint thinners, kerosene, jet fuel, acids, and sodium) were disposed of in several trenches and auger holes. Subsequently, these disposal areas have been capped with high-density polyethylene. Some site characterization data identified in the WAG 6 RI Plan have been collected, and the final RI was expected to be issued in 1991. Tritium, ^{60}Co, ^{90}Sr, and ^{137}Cs were the principle radioactive contaminants found in samples of 35 groundwater wells. These same contaminants were found in surface water and in both surface and subsurface soil samples. Trace levels of TRU isotopes were also found in two wells and two surface samples. Trace levels of several metals and solvents were found in a few wells. Only trace levels of metals or organics were found in surface water or soil samples. Solomon et al. (1988) and Ashwood and Spalding (1991) sampled wells in burial trenches and found numerous radioisotopes, heavy metals, VOCs, and nitrates. Stream gravel samples indicate that SWSA 6 has been a source of ^{60}Co, ^{90}Sr, ^{137}Cs, and possibly of copper, molybdemun, and zinc to WOL. No indication of organic contamination was found in the stream gravel samples. In addition, no radionuclide contamination has been detected in samples from the small drainage down-gradient from the EWB. Existing monitoring data do not permit continuing releases from SWSA 6 to be quantified, primarily because of the absence of routine flow monitoring and sampling of the four tributaries that drain the WAG. A monitoring network on these streams is needed to estimate past, and determine continuing, contaminant discharges to WOL.

<u>WAG 7</u>

Description: WAG 7 is in Melton Valley about 1.6 km (1 mi) southwest of the main plant area. The major SWMUs in this WAG, in terms of radioactive contamination, are seven pits and trenches used to dispose of liquid LLW between 1951 and 1966. WAG 7 also includes a decontamination facility, three leak sites, a storage area containing shielded transfer tanks and other equipment, and seven fuel wells containing the acid solutions of enriched uranium from Homogeneous Reactor Experiment (HRE) fuel. WAG 7 drains to the East and West Seep tributaries to WOL, to WOC directly, and to two unnamed tributaries to WOC.

Releases: More than 1,100,000 Ci of liquid LLW, primarily ^{90}Sr, ^{106}Ru, and ^{137}Cs, was transferred to the waste pits and trenches; another 2000 Ci of ^{137}Cs was placed in the shielded transfer tanks, and nearly 4 kg of ^{235}U in liquid form was placed in the HRE fuel disposal auger holes. RCRA-regulated contaminants may also be present in this WAG, but data are insufficient to determine which ones. Characterization studies suggest that WAG 7 has been a source of ^{3}H, ^{60}Co, ^{90}Sr, ^{99}Tc, chromium, and zinc. Studies by Olsen et al. (1983) have also shown the presence of ^{233}U in the vicinity of Trench 7. No organic contamination traceable to WAG 7 has been found. Existing monitoring data are insufficient to characterize contaminant releases from WAG 7. Additional data will be required to determine the nature and extent of past and continuing releases.

WAG 8

Description: WAG 8 is in Melton Valley south of the main plant area and north of MB. Most of the reactor facilities other than those in WAG 1 are in Melton Valley. WAG 8 includes the Molten Salt Reactor Experiment (MSRE) and the High Flux Isotope Reactor (HFIR). In addition, WAG 8 includes associated tank and piping systems, six leak sites and an old transfer line, five surface impoundments, a contractor spoils area, and RCRA-permitted hazardous waste storage facilities. Liquid LLW and process wastes from the reactors and associated facilities are collected on-site in tanks and then pumped to the main plant area for storage and treatment. Wastes from the Homogeneous Reactor Experiment (HRE) (WAG 9) were pumped using the same transfer system. WAG 8 drains directly into MB and into the West Seven tributary to MB.

Releases: The following summary is derived from the environmental data package for WAG 8. There is no inventory on the contents of the LLW collection and storage tanks, which are still in active use. Historical data are insufficient to determine whether or not any contamination remains at the two leak sites in WAG 8. The EP-toxicity test found that samples of the sludge in the four impoundments were not hazardous. There is probably less than 10 Ci of radioisotopes in these ponds. There is no indication that radioactive or hazardous wastes were ever introduced into the waste treatment facilities that are part of the ORNL sewage treatment system. The solid waste storage facilities are used to store hazardous and mixed wastes. However, stream gravel studies by Cerling and Spalding (1981) have identified WAG 8 as a major source of ^{60}Co and, to a lesser extent, ^{137}Cs to Melton Branch. The WAG has also been a source of copper, chromium, and zinc. Recent monitoring data suggest that WAG 8 is the source of about half of the ^{60}Co entering the WOC/WOL system. The WAG contributes negligible amounts of other radionuclides. Additional data will be required to determine past and continuing contributions of heavy metals (especially chromium and zinc) and organics from WAG 8 to WOC. No data are presently available on organic contaminants.

WAG 9

Description: WAG 9 is in Melton Valley about 1 km (0.6 mi) southeast of the main plant area just south of Melton Valley Drive. This WAG, consisting of three SWMUs, includes the HRE pond, LLW collection and storage tanks, and a septic tank serving the HRE, now the Nuclear Safety Pilot Plant (NSPP). The HRE pond was constructed in 1955 as a waste storage impoundment for condensate from the HRE waste evaporator. The pond was filled with soil and capped with asphalt in 1970. WAG 9 drains to the HRE (Homogeneous Reactor Test [HRT]) tributary to MB.

Releases: Stansfield and Francis (1986) found approximately 750 Ci of gross beta activity in the sediments of the HRE impoundment. The primary isotopes contributing to this activity were ^{90}Sr and ^{137}Cs. The sediments passed the EP-toxicity test. Tritium and ^{90}Sr were found in groundwater downgradient from the HRE impoundment, but only trace levels of metals and organics were found (Stansfield and Francis 1986). Existing monitoring data are insufficient to separate contributions from WAG 9 and WAG 5. In addition, monitoring data are not routinely collected for detection of trace metal or organic contaminants. Additional data will be required to determine the contributions from WAG 9 to past and continuing contamination of WOC.

WAG 10

Description: WAG 10 consists of the injection wells and grout sheets from four SWMUs, two of which were experimental sites used in the development of the hydrofracturing process at ORNL. The other two sites were operating facilities (now inactive) used to dispose of ORNL's liquid LLW. All four SWMUs are located in Melton Valley; however, they are not adjacent to one another (Fig. 7). WAG 10 is significantly different from the other WAGs in that its grout sheets are at depths of 90 to 300 m (300 to 1,000 ft) below ground.

Releases: Approximately 12,000,000 L of liquid wastes were injected into the fractured shale at the two major hydrofracture sites. Except for the isotopes listed in Table 1 above, little is known about the contaminants that may have been included in the grout mixtures. Analyses of similar wastes currently in storage reveal only negligible levels of heavy metals and no organics. Samples collected from groundwater wells, installed to monitor releases from the grout sheets, have detected ^{90}Sr contamination. No other contaminants have been found, and there is no indication of WAG 10 contamination reaching shallow groundwater or surface water. There is no monitoring data to determine the input, if any, of WAG 10 contaminants to WOC. Until the RI for WAG 10 is complete, it is unclear whether additional monitoring data will be needed.

WAG 13

Description: WAG 13, part of what is now called the 0800 Area, is west of State Highway 95 (White Wing Road) near the Clinch River. There are two SWMUs within WAG 13, both associated with research on transport of ^{137}Cs through the environment. The larger SWMU drains into the Clinch River downstream from the mouth of WOC. However, portions of the smaller SWMU (a 20 m^2 site where 0.015 Ci of ^{137}Cs was sprayed over the surface) may drain to Duck Creek, a tributary to WOC below WOD.

Releases: Only one small (200 m^2) SWMU (13.2) in this WAG drains into WOC. Approximately 15 mCi of ^{137}Cs in liquid form was sprayed on the surface of this SWMU in 1964. Almost one half-life (30 years), in terms of this material, has passed since that time. An aerial radiological survey of the Oak Ridge Reservation (ORR) (Fritzche 1987) conducted in 1986 showed the presence of ^{137}Cs at the other SWMU, but the radiological exposure maps do not show SWMU 13.2 as a separate source of radiation. The ^{137}Cs was applied to study environmental transport. Therefore, it is likely that some portion migrated into the WOCE below Whiteoak Dam. Stream gravel surveys have not detected ^{137}Cs in the reach that drains SWMU 13.2; however, ^{90}Sr levels were about 4 times background. Existing monitoring data do not provide to provide enough resolution to determine if WAG 13 is a source of ^{137}Cs. An RI plan is currently being prepared for WAG 13, and execution of that plan should help to determine if the WAG is a source of ^{137}Cs to the WOCE.

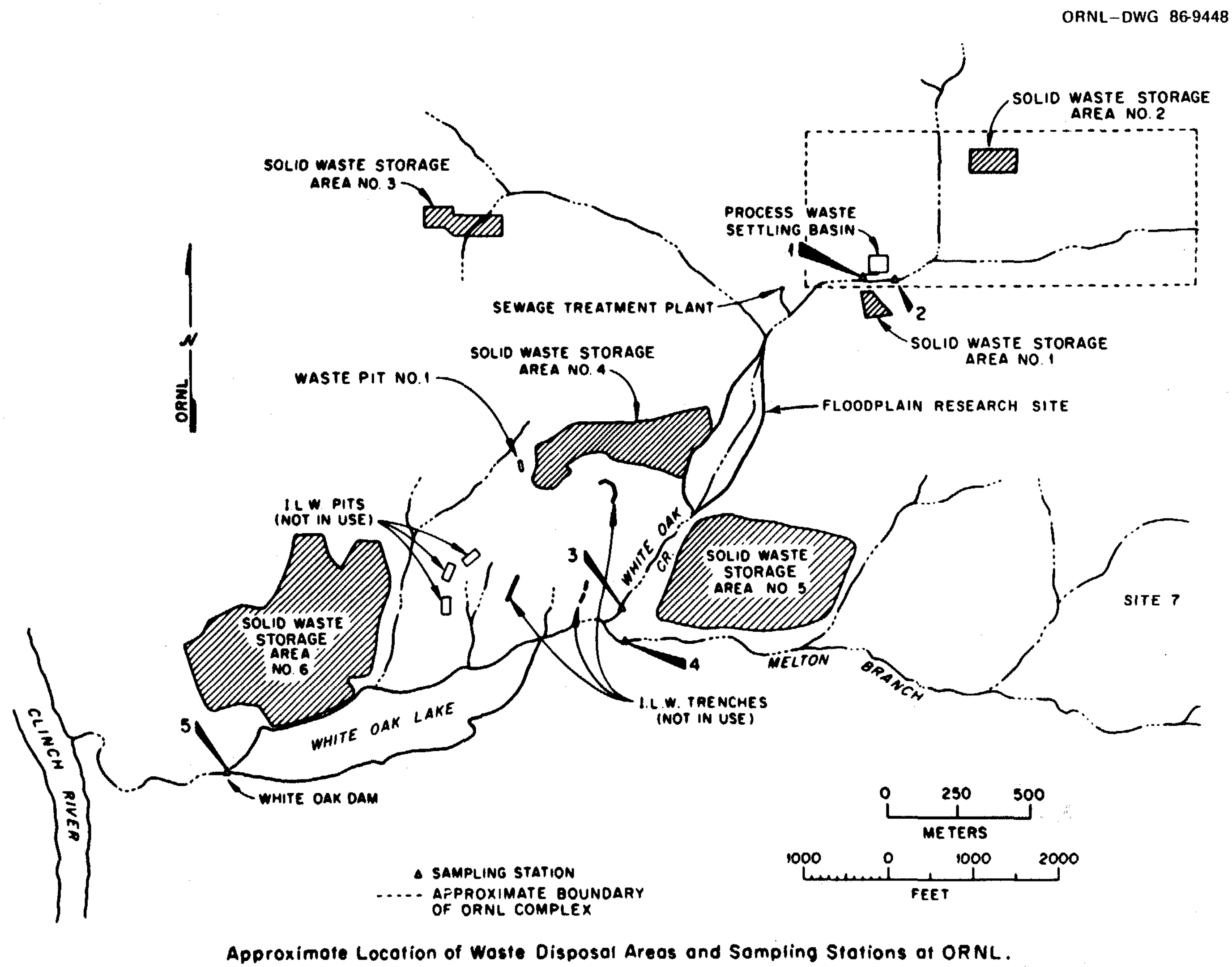

Fig. 7. Schematic of the WOC watershed showing potential area contamination sources.

WAG 17

Description: WAG 17 is about 1.6 km (1 .0 mi) east of the main plant area, south of Bethel Valley Road. This area is the major craft and machine shop area for ORNL and includes the shipping, receiving, machine shops, carpenter shops, paint shops, lead burning facilities, welding facilities, garage facilities, and material storage to support ORNL operations. The WAG includes 9 SWMUs, all tanks. WAG 17 drains into WOC just south of Bethel Valley Road. WAG 17 effluents, entering WOC approximately 5 km (3 mi) upstream from WOL, may ultimately reach WOL and the Clinch River.

Releases: The SWMUs in WAG 17 are all tanks, and only three of these are underground. These tanks have a volumetric capacity of 39,000 gal of domestic sewage, ~13,000 gal of waste oil, and 5000 gal of photographic wastes. In addition to the SWMUs, four underground tanks (capacity ~31,000 gal) are used for diesel fuel and gasoline, and one 4000-gal, aboveground tank is used for waste oil. There are no reports of releases of radionuclides or hazardous materials from WAG 17; however, stream gravel surveys show that ^{137}Cs may have been released in the past. The surveys also suggest the presence of cadmium, chromium, copper, and zinc. In addition, semi-volatile organics were found to be present as tar-like grains on the gravels. Existing monitoring data are insufficient to separate WAG 17 inputs from those of WAG 1, and dilution may obscure the contribution of WAG 17. Additional data will be required to determine continuing contaminant contributions, if any, from WAG 17 to WOC.

1.3 OTHER PROGRAMS

1.3.1 Environmental Surveillance

To meet regulatory requirements and DOE directives and to provide continuity of data on environmental media at unregulated locations, ESP conducts a comprehensive environmental surveillance monitoring program to determine contaminant releases from ORNL facilities, from the Laboratory site, and, with the support of the other Energy Systems facilities, from the ORR (Energy Systems 1989, 1990a, b, c). The major regulatory legislation affecting the environmental program at ORNL includes the Clean Water Act (CWA), the Clean Air Act (CAA), RCRA, and the Superfund Amendments and Reauthorization Act (SARA). In addition, DOE Order 5400.1, "General Environmental Protection Program," established requirements, authorities, and responsibilities for assuring compliance with applicable Federal, State, and local environmental protection laws and regulations. This Order established guidelines for radiological and nonradiological monitoring. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," sets guidelines for radionuclide releases to the environment. Finally, Draft DOE Order 5400.6, "Radiological Effluent Monitoring and Environmental Surveillance," established radiological monitoring requirements and guidance on procedures.

Environmental monitoring consists of two major activities: (1) effluent monitoring - collecting and analyzing samples or measurements of liquid and gaseous effluents; and (2) environmental surveillance - collecting and analyzing samples, or direct measurements of air, water, soil, biota, and other media from DOE sites and their environs.

Monthly or quarterly samples, for each of the media sampled, are presented in quarterly environmental surveillance reports (Energy Systems 1989, 1990a, b, c). Summary tables are included which give the number of samples collected during the period, and mean, maximum, minimum, and standard error of the mean values for some parameters. Maps are provided to identify sampling locations for most parameters. In addition, mean values of some parameters are compared to applicable guidelines, criteria, and standards in order to evaluate the impact of effluent releases or environmental concentrations. A description of the types of data available from ESP's environmental surveillance program is presented in Sect. 3.4.

1.3.2 National Pollutant Discharge Elimination System

The ORNL National Pollutant Discharge Elimination System (NPDES) permit (TN0002941) expired March 31, 1991. This permit had authorized ORNL to discharge to receiving waters of WOC, NWT, MB, Fifth Creek, and First Creek on the WOC watershed in compliance with the Clean Water Act and in accordance with effluent limitations, monitoring requirements, and other conditions set forth in the permit. A permit renewal application was submitted in September 1990 (DOE 1990). The renewal application was filed more than 180 days prior to the expiration of the existing permit. According to regulations, ORNL, having met this condition, is qualified to operate under the guidelines of the old permit until the regulatory agency (EPA) acts on the new application (C. K. Valentine, Oak Ridge National Laboratory, personal communication to D. M. Borders, University of Tennessee, August 1991).

Water quality analyses have been conducted to monitor the effluent quality of discharges from ORNL operations. Permit limitations were based on various state and federal guidelines determined to be applicable to the ORNL facility. Available data collected under the terms of the expired permit, optimization studies, current toxicity information, and review of current state and federal guidelines have been considered in the development of proposed limitations for the permit renewal. These limitations are being considered for all discharges at ORNL, and special conditions for the permit application have been developed. These include mercury, PCB, and Radiological Monitoring Plans, which are being evaluated for modification and will be submitted as addendums to the permit application. Best Management Practices have also been developed for submittal.

1.3.2.1 Outfalls

Existing outfalls at ORNL include the Sewage Treatment Plant (X01), Coal Yard Runoff Facility (X02), Nonradiological Wastewater Treatment Plant (X12), ambient water quality monitoring stations on MB (X13), WOC (X14), WOD (X15), Category I, II, and III outfalls, cooling towers, and miscellaneous outfalls. Each outfall is analyzed according to DOE, permit, and regulatory requirements. These outfalls are described in greater detail in Section 3.2.3.

1.3.2.2 Stormwater monitoring

A new provision to the NPDES regulations was promulgated after ORNL had submitted the application for permit renewal. The EPA and the Tennessee Department of Health and Environment (TDHE) stormwater monitoring regulations, which were effective November

16, 1990 (EPA, 1990), require ORNL to submit stormwater permit applications for new and/or previously unpermitted stormwater outfalls associated with industrial activity by November 17, 1991. The regulations specifically require permit applications for industrial facilities which are subject to stormwater effluent limitations guidelines, sites used for treatment, storage, or disposal of hazardous waste, landfills, land application sites and open dumps which have received any industrial waste, and areas where industrial activity has taken place in the past and significant materials remain and are exposed to stormwater, among others. Because of the diversity of research activities, waste-generating operations (including radioisotope production, experimental reactors, hot cells, and pilot plants), and the legacy of environmental waste sites requiring remediation in the future, ORNL falls under most of the categories of industrial activity which require submission of a stormwater application. By interpretation, all of the WAGs must be sampled to meet ORNL's obligation under EPA's new stormwater regulation.

The Environmental Compliance Section (ECS) of the Office of Environmental Compliance and Documentation (OECD) is developing a Stormwater Monitoring Compliance Plan for inclusion in the Stormwater Application (E. Wright, Oak Ridge National Laboratory, personal communication to D. M. Borders, The University of Tennessee, Knoxville, August 1991). The ECS plans to sample stormwater at approximately 35 sites in the 20 ORNL WAGs excluding WAGs 10, 11, 15, 18, and 20. WAGs 15 and 20 will be the responsibility of the Y-12 Plant. Eleven sites in WAG 1 will have the lowest priority because stormwater runoff has been sampled in the main plant area for several years and the information has been submitted to the TDHE.

The stormwater regulations are aimed at characterizing the first discharge associated with the storm event (grab sample within the first 30 minutes of runoff) and characterizing the runoff over the course of the storm (composite sample collected over at least three hours during the storm). Staff members in ERP and ESD have helped identify existing stream monitoring stations, select sampling sites, and disseminate pertinent information, including Environmental Restoration activities and monitoring plans. The ERP has an interest in storm sampling at many of the same locations. Therefore, future efforts will be coordinated, where practical, to avoid duplication of effort and to satisfy the requirements of ORNL and ERP.

1.3.3 Active Sites Environmental Monitoring Program

The Active Sites Environmental Monitoring Program (ASEMP) (Ashwood et al. 1990), established in 1989 by Solid Waste Operations and conducted by ESD in accordance with chapters II and III of DOE Order 5820.2A, provides for early detection and performance monitoring at active LLW disposal sites and TRU waste storage sites at ORNL. The scope of this program includes all ORNL waste disposal sites that were active on, or after, September 1988, the date the order was issued. These active sites include the high-activity and low-activity silos, the high-activity auger holes, the fissile wells, the asbestos silos, the suspect waste landfill, the Tumulus Disposal Demonstration Project (Tumulus I), Tumulus II, the Interim Waste Management Facility (IWMF) in SWSA 6, and the TRU waste storage sites in SWSA 5 North. In addition, the program addresses monitoring activities associated with the Hillcut Disposal Test Facility (HDTF) and the Interim Corrective Measures (ICM) capped areas in SWSA 6. The objective of the ASEMP is to provide for early detection of radionuclides leaking from storage or disposal facilities before the releases pose a threat to public health or the environment.

The basic monitoring strategy of the ASEMP includes:

1. Quarterly sampling of surface drainages in SWSA 6 to identify changes in contaminant levels due to the ICM capped areas and the Suspect Waste Landfill and at SWSA 5 North to determine if TRU contamination is leaving the site. Water samples are analyzed for gross alpha, gross beta, gamma activity, and ^{3}H; plus total organic carbon (TOC) and total suspended solids (TSS) at the ICM capped areas.

2. Quarterly sampling of intratrench wells near LLW sites; wells near fissile wells, auger holes, and asbestos silos; wells surrounding Tumulus I and II; and wells located in and around SWSA 5 North. Samples will be analyzed for gross alpha, gross beta, and gamma activity. Water measurements in wells surrounding the HDTF are taken weekly. Once a year, half the wells surrounding Tumulus I and II and half the wells surrounding the IWMF will be sampled and analyzed for cations, anions, and selected indicator organic compounds. At SWSA 5 North, if gross alpha activity above the action level (1.0 Bq/L) is detected, samples will be analyzed for the specific alpha-emitting isotope.

3. Continuous monitoring of water levels in wells surrounding Tumulus I and II, and in four wells in the ICM capped areas in SWSA 6.

4. Monthly measurement of water levels in piezometers and wells installed in trenches under the ICM capped areas.

5. Continuous monitoring of pad runoff flow and underpad drainage at Tumulus I or II (only one at a time will be operational) and at the IWMF at SWSA 6. Storm events at each site will be sampled and analyzed for gross alpha, gross beta, gamma activity, and TOC.

6. Monthly sampling of French drain discharge from the IWMF at SWSA 6. Samples will be analyzed for gross alpha, gross beta, gamma activity, ^{3}H, ^{90}Sr, TOC, and TSS.

7. Quarterly surveying of gamma scintillometer at Tumulus I and II and the IWMF at SWSA 6. A single soil sample will be taken during each survey at Tumulus I and II. At the IWMF, surface soil samples will be taken at two randomly selected locations and from any locations found to be above background. These will be analyzed for gross alpha, gross beta, and gamma activity.

The ORNL ASEMP plan has been implemented by staff and subcontractors of ESD with key interfaces with Solid Waste Operations and the ICM Program, among others. This plan addresses monitoring activities associated with the HDTF in SWSA 6, even though the facility does not meet the definition of an active site. In addition, monitoring of the ICM capped areas in SWSA 6 is addressed, although it is funded separately from the Active Sites tasks. The ASEMP plan is presently being revised and some changes to the monitoring activities discussed above will occur.

1.3.4 Biological Monitoring and Abatement Program

The Biological Monitoring and Abatement Program (BMAP) was developed in response to a requirement of the National Pollutant Discharge Elimination System (NPDES) permit issued to ORNL on April 1, 1986. Part III: Special Conditions of the NPDES permit calls for a plan for biological monitoring of the Clinch River, White Oak (Whiteoak) Creek, Northwest Tributary, Fifth Creek, First Creek, and Melton Branch. The BMAP consists of six major tasks that address radiological and nonradiological contaminants in the aquatic and terrestrial environs: (1) toxicity monitoring, (2) bioaccumulation monitoring of nonradiological contaminants in aquatic biota, (3) biological indicator studies, (4) instream ecological monitoring, (5) assessment of contaminants in the terrestrial environment, and (6) radioecology of WOC and WOL.

The BMAP was developed to meet three objectives:

1. sufficient data is to be provided to determine whether the effluent limits established for ORNL protect and maintain the classified uses of WOC and its major tributaries. These streams have been classified by the TDHE for growth and propagation of fish and aquatic life, irrigation, and livestock watering and wildlife.

2. The BMAP provides ecological characterizations of WOC and its tributaries and of WOL to document ecological impacts of past and current operations, and to identify contaminant sources that adversely affect stream biota. This information has helped to develop RI/FS plans and to assess remedial action alternatives within the ORNL ERP.

3. The BMAP evaluates remedial actions taken by the ERP and the Water Pollution Control Program (WPCP) by documenting the effects of those actions on stream biota. The long-term nature of the BMAP ensures that the effectiveness of remedial measures will be properly evaluated.

The BMAP water quality sampling program was initiated in mid-1986 as a component of the periphyton monitoring program. This program collects monthly water samples at the periphyton monitoring sites in the WOC system. Grab samples are collected from each of the nine periphyton monitoring sites (Fig. 8). Samples are analyzed for dissolved organic carbon (DOC), soluble metals, pH, alkalinity, conductivity, hardness, phosphorus, nitrate and nitrite, ammonia, and suspended solids. This program was intended to augment the NPDES water quality monitoring program by providing data for additional sites and parameters not included in the NPDES permit. The BMAP water quality sampling program also provides background information for ERP activities.

Water samples have been collected for chemical analyses not only by BMAP but under a second component of the BMAP known as the Toxicity Monitoring Studies. Through 1990, 15 sites on 5 streams had been evaluated for toxicity 29 times. The 15 sites used for these ambient studies were initially selected to encompass both point and nonpoint source contributions to toxicity in receiving streams. Four of the 15 sites (upstream on First Creek, Fifth Creek, WOC and MB) have no contaminants in toxic concentrations and are used as reference sites. Samples collected for ambient toxicity tests on water are analyzed for conductivity, alkalinity, hardness, pH, and free and total residual chlorine (TRC). Toxicity

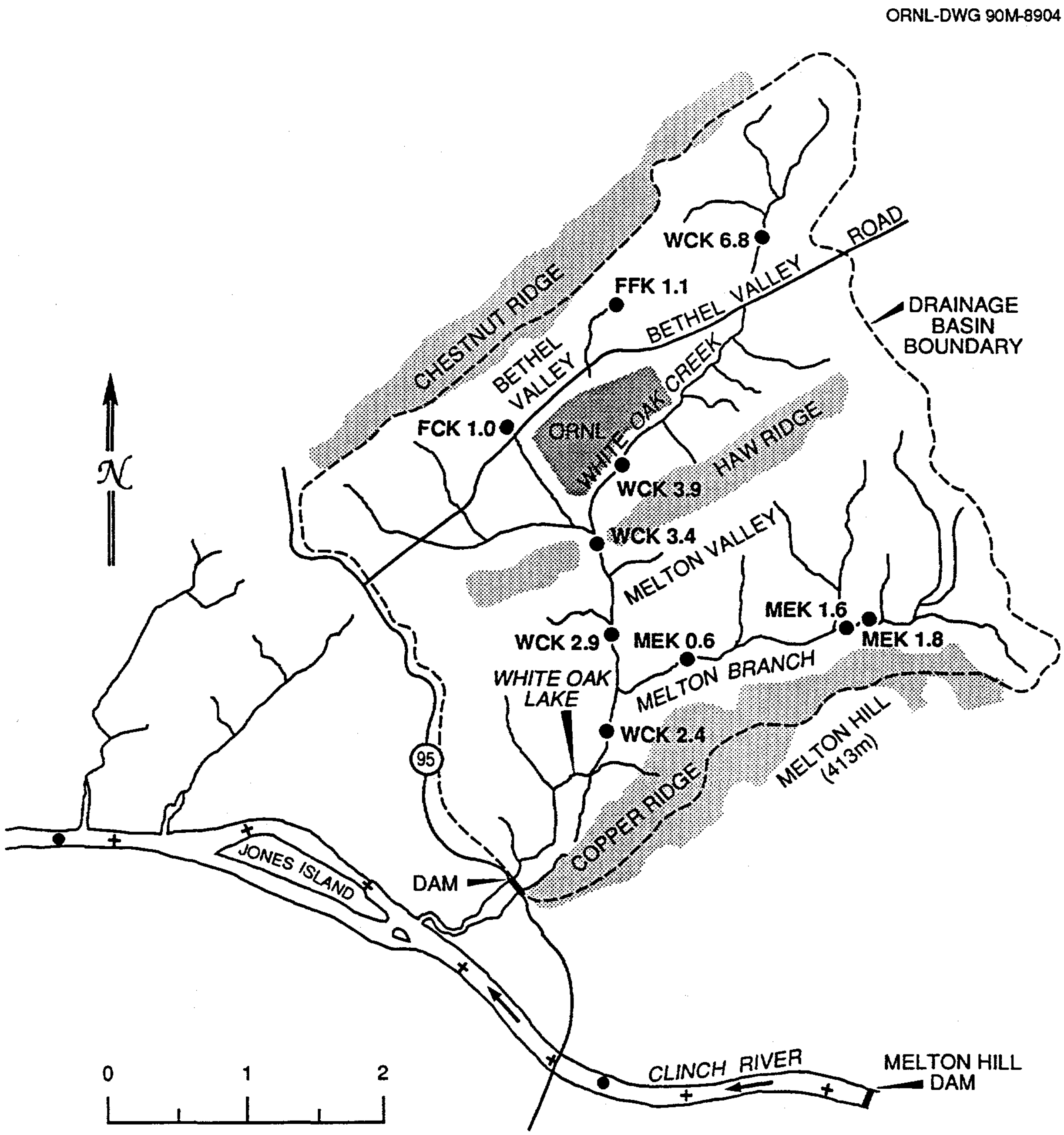

Fig. 8. Periphyton monitoring sites in the Whiteoak Creek watershed.

Monitoring Studies provide an understanding of ambient toxicity patterns in streams at ORNL and provide evidence of environmental degradation.

BMAP radioecology studies in WOL have been conducted to provide information on concentrations of radionuclides in soil core samples from the WOL floodplain. These studies provide the preliminary data necessary to design a sampling plan that will determine the inventory of contaminants in the floodplain. Twenty-three soil cores were collected and analyzed for gamma-emitting radionuclides. Cores were divided into 2.5 cm sections and analyzed for ^{137}Cs and ^{60}Co to determine profiles of concentration vs depth. A composite sample was taken from 10 cores for ^{90}Sr analyses, and results showed that ^{137}Cs and ^{60}Co were the most abundant gamma-emitting radionuclides. In addition to providing preliminary data for an inventory of contaminants, the BMAP radioecology studies will identify potential environmental pathways that could lead to human exposure.

In 1988, the investigation of contaminant transport, distribution and fate in the WOC Embayment-Clinch River-Watts Bar Reservoir system was removed from the responsibility of the BMAP and incorporated into the RFI for the Clinch River.

1.3.5 Groundwater Protection Program

The ORNL Groundwater Protection Program (GWPP) was established to comply with DOE Order 5400.1 (see Sect. 1.3.1) and is administered by the Groundwater Protection Program Manager (GPPM). All organizational activities involving regulatory-related groundwater programs and projects will be coordinated under the GWPP. The ORNL GWPP is composed of members from the ESP Section of the OEHP, the ORNL Environmental Safety & Health (ES&H) Executive Committee, the Energy Systems Groundwater Program Office, the OECD, the Energy Systems Engineering Division, ORNL ER activities, and the Oak Ridge Hydrology Support Program (ORHSP). The GWPP manager serves as the central coordinator and primary interface with these and other related programs. Each element of the GWPP has specific functions that are carried out by the project manager/supervisor of the element. The GWPP, through formal coordination, will prevent unnecessary expenditures and duplication of activities among Energy Systems organizations and their subcontractors. The GWPP will promote interactions with DOE and regulatory agencies. Additionally, the GWPP will provide a sound technical basis for decisions and actions regarding hydrologically related matters, and will promote consistency in hydrologically related activities.

The Special Program Planning Requirements section of the Order specifies the preparation of a groundwater protection program plan (Draft Groundwater Protection Program Management Plan, ORNL, May 1991) for each DOE site covering each of the following activities:

1. documenting the groundwater regime with respect to quantity and quality;

2. designing and implementing a groundwater monitoring program that supports resource management and complies with applicable laws and regulations;

3. conducting a management program for groundwater protection and remediation, including specific Safe Drinking Water Act (SDWA), RCRA, and CERCLA actions;

4. summarizing and identifying areas that may be contaminated with hazardous substances;

5. developing strategies for controlling sources of the contaminants;

6. conducting a remedial action program that is part of the site CERCLA program required by DOE Order 5400.4; and

7. decontaminating and decommissioning of sites and conducting other remedial programs contained in DOE directives.

These activities have been performed by various organizations in the past with no formal coordination. The GWPP will ensure effective planning and execution of the regulatory requirements associated with groundwater, primarily by coordinating efforts among the organizations performing the activities.

Groundwater quality monitoring at ORNL can be categorized according to three requirements: environmental surveillance, compliance, and characterization. Environmental surveillance monitoring provides data for evaluation of the effects of plant operations on groundwater. Compliance monitoring is performed to comply with all relevant regulatory, State, Federal, and local requirements. Groundwater quality monitoring is performed to characterize the extent and degree of contamination due to past practices. This monitoring is performed primarily in support of the ERP. The GWPP management plan attempts to integrate all three monitoring categories to develop an effective, plant-wide groundwater monitoring strategy.

1.3.6 Oak Ridge Reservation Hydrology and Geology Studies

The Oak Ridge Reservation Hydrology and Geology Study (ORRHAGS) (McMaster in press) was established in 1989 to provide essential information about the hydrologic and geologic environment of the ORR to those responsible for managing environmental issues. ORRHAGS is an integrated study of the hydrology, geology, and soils of the reservation with emphasis on contaminant migration. It supports activities in environmental monitoring and restoration, waste management, and regulatory compliance.

In 1989, the ORR was placed on the EPA's National Priorities List. In response, a FFA has been developed among DOE, EPA Region IV, and the TDHE. Carrying out the terms of the FFA and DOE Order 5400.1 (see Sect. 1.3.1) requires a complete (as much as possible) understanding of the hydrogeologic regimes of the ORR. While site investigations, site characterization, and remedial actions at the three DOE facilities have been site-specific (small scale) in scope, ORRHAGS was established to determine larger-scale hydrologic characteristics of the ORR.

2. SITE DESCRIPTION

The WOC watershed is located primarily in the Roane County portion of the Oak Ridge Reservation. The headwaters region of WOC, making up the northeast corner of the watershed, lies partially in Anderson County. The WOC watershed is bounded by Copper Ridge to the south, White Wing Road (State Highway 95) to the west, Chestnut Ridge to the north, and approximately the Roane/Anderson County boundary to the east. The majority of ORNL's facilities, active and inactive waste management areas, and potential sources of contaminants lie within the watershed boundaries. Therefore, most waste effluents produced as a result of ORNL operations are released into the WOC system.

Since WOL was created in 1943, a number of studies have been undertaken to determine contaminant sources, quantities of contaminants released into and retained in the lake, and the geology and hydrogeology of WOC/WOL. Table 2 summarizes some of the more important studies conducted since 1945. In some instances, the studies referenced in Table 2 represent summaries of the information developed; individual investigators have reported in greater detail their efforts in other reports and papers. An extensive listing of data and reports pertinent to the RAP may be retrieved from the RAP DIMS(Voorhees et al. 1988, Voorhees et al. 1989, Hook et al. 1990).

2.1 WHITEOAK CREEK

The WOC rises from springs on the southwest slopes of Chestnut Ridge and, with its tributaries, drains much of Bethel and Melton Valleys (which include ORNL) to the Clinch River (Fig. 1). The waters of WOC are impounded by Whiteoak Dam (WOD), constructed 1.0 km (0.6 miles) upstream from the Clinch River in 1943, to form Whiteoak Lake (WOL) which serves as a holding pond for ORNL waste effluents. As this report went to press, a retention dam was being constructed at the mouth of WOC on the Clinch River to limit the movement of contaminated sediments to the off-site environment. The drainage areas upstream from the Clinch River and Whiteoak Dam (WOD) are approximately 16.8 km^2 (6.5 miles^2) and 16.0 km^2 (6.15 miles^2), respectively (Martin Marietta Energy Systems, Inc. 1985). Elevations in the watershed range from 226 m (741 ft) above mean sea level (MSL) at the mouth of WOC to 413 m (1355 ft) above MSL at the top of Melton Hill, the highest point on the Oak Ridge Reservation (McMaster 1963; McMaster and Waller 1965).

2.2 WHITEOAK DAM

WOD is a low-head structure with a normal lake elevation of 227.1 m (745 ft). The reservoir is only 0.9 m (3 ft) above full-pool elevation in the Clinch River, which is 226.6 m (742 ft). Recent work by Cox et al. (in press) indicates that the volume of WOL at normal pool level is approximately 43,890 m^3 (1,546,330 ft^3). Flow from WOL discharges through a weir and a concrete-box culvert to the lower reach of WOC. In 1983, the flow system at the dam was modified to increase flood discharge capacity to approximately 56.6 m^3/s (2000 ft^3/s). Tschantz (1987) estimated the 100-year flood peak discharge to be approximately 44.6 m^3/s (1574 ft^3/s).

Table 2. Historical changes in the surface of Whiteoak Lake and major events associated with significant changes in the lake

DATE	SURFACE AREA (ha)	EVENTS	REFERENCES
1941		Highway fill and culvert installed by TVA	Smith (1945) as in Krumholz (1954)
1943	14.5	(a) Sheet piling dam installed with spillway with vertical sliding gate; (b) Generation of radioactive waste at ORNL began and lake served as final settling basin (750 ft MSL)	(a) Krumholz (1954); (b) Clinch River Study Steering Committee (1967)
1944	NA	Dikes at WOC km 3.3 and 3.9 washed out (7.75 in., 26 h, 3.5 in. runoff)	Setter and Kochtitsky (1950)
1945	12.2	Investigation of structural strength of dam (746.5 ft)	Oakes et al. (1982a)
1948	10.3	Lake lowered to 745.5 ft to facilitate sediment sampling, normal operation from 1948 tko 1955 varied from 747-749 ft)	Oakes et al. (1982a)
1953	NA	Lake partially drained during rotenone survey of fish populations	Oakes et al. (1982a)
1955	2.8	Lake drained; radionuclides in lake sediment and water believed to be in equilibrium so lake served no useful function in retaining radioactivity but could function as an emergency storage basin.	Clinch River Study Steering Committee (1967)
1956	0.4	Significant releases of ^{137}Cs probably from erosion of freshly exposed sediment after lake was drained.	Lackey (1957)
1959	NA	Gate structure renovated to prevent inflow of backwaters from Clinch River	Clinch River Study Steering Committee (1967)
1960	3.2	Dam closed, surface level raised	Kolehmainen and Nelson (1967)
1963	6.0	Completion of Melton Hill Dam	Kolehmainen and Nelson (1967)
1967	8.1	None reported	McMaster (1967)
1969	10.5	None reported	Kolehmainen and Nelson (1967)
1979	4.6	Lake level gradually dropped from 745 to 742 ft due to potential instability of the dam	Oakes et al. (1982a)
1980	6.9	Construction of a berm to stabilize dam was completed	B~~l~~oyle et al. (1982)
1983	6.9	Discharge channel and weir constructed, roadbed rerouted	
1988		Estimate of surface area and volume (43,900m^3) at lake level of 745 ft	Cox et al. (1991)

not in refs
c/b Stanyness? 67

When the Watts Bar Reservoir is near full pool level (approximately April to October), backwater from the Clinch River creates an embayment in WOC below WOD. The WOC Embayment (WOCE) extends 1 km (0.6 mi) downstream from WOD to its mouth at Clinch River kilometer 33.5 (Clinch River mile 20.8). Water levels and flow in the WOCE are largely controlled by the operation of Melton Hill Dam (3.7 km [2.3 miles] upstream on the Clinch River) and summer and winter pool levels on Watts Bar Reservoir, formed by Watts Bar Dam (94 km [58.8 miles] downstream on the Tennessee River). When the generators at Melton Hill Dam are operating, the release of water from the dam can increase the depth of water at the mouth of the embayment by over 0.3 m (1 ft) in two minutes (Fig. 9) and also cause backflow into the embayment. When the generators shut down, the water gets shallow almost as quickly. Thus rapid change in water level and pulsing of flow caused by daily peaking operations at Melton Hill Dam are contributing to the erosion of sediments from the embayment. Figure 10 shows the trend in water levels at the mouth of the embayment during a wet winter month. Water levels typically vary by approximately 0.6-1.2 m (2-4 ft) per day, with monthly ranges up to 2.5 m (8 ft) or more.

2.3 GEOLOGY

Four major geologic units underlie the WOC drainage basin. All formations strike northeast at about 56° and dip southeast at angles commonly between 30° and 40°. The Knox Group (Cambrian and Ordovician Age) underlies Chestnut and Copper Ridges, which bound the WOC drainage basin to the north and south. The Knox Group, mostly composed of cherty dolomite in which sinkholes and caverns have developed, is the principal water-bearing formation in the watershed. The springs along the southern slopes of Chestnut Ridge are the principal sources of the base flow of WOC's upper portion (McMaster and Waller 1965).

The Chickamauga Group (Ordovician Age) underlies Bethel Valley, which includes the ORNL Main Plant area, and SWSAs 1, 2, and 3 (Fig. 7). This formation is mostly limestone, although shales, siltstones, and bedded chert comprise a significant part of the formation. Generally, the strata are thin to medium bedded. Solution openings and fractures occur in the Chickamauga, but the openings are smaller than in the Knox Group.

The Conasauga Group (Cambrian Age) underlies Melton Valley, including SWSAs 4, 5, and 6, and the pits and trenches area (Fig. 7). The general sequence through the Conasauga formation is gradational, from shale at its base to bedded limestone at the top. WOL and the lower part of WOC rest on limestone or shaley limestone of the Conasauga Group.

The Rome Formation (Cambrian Age) is exposed along Haw Ridge. In general, the formation consists of sandstone, shale, siltstone and locally, dolomite.

The Knox Group and the underlying Maynardville Limestone of the Consauga Group form the Knox aquifer (Solomon et al. in press), which is the source of most natural base flow in streams in the WOC basin. The Rome Formation, the Conasauga Group and the Chickamauga Group discharge smaller quantities of water to the streams. Water is found in weathered rock of all units near land surface.

ORNL DWG 91-14923

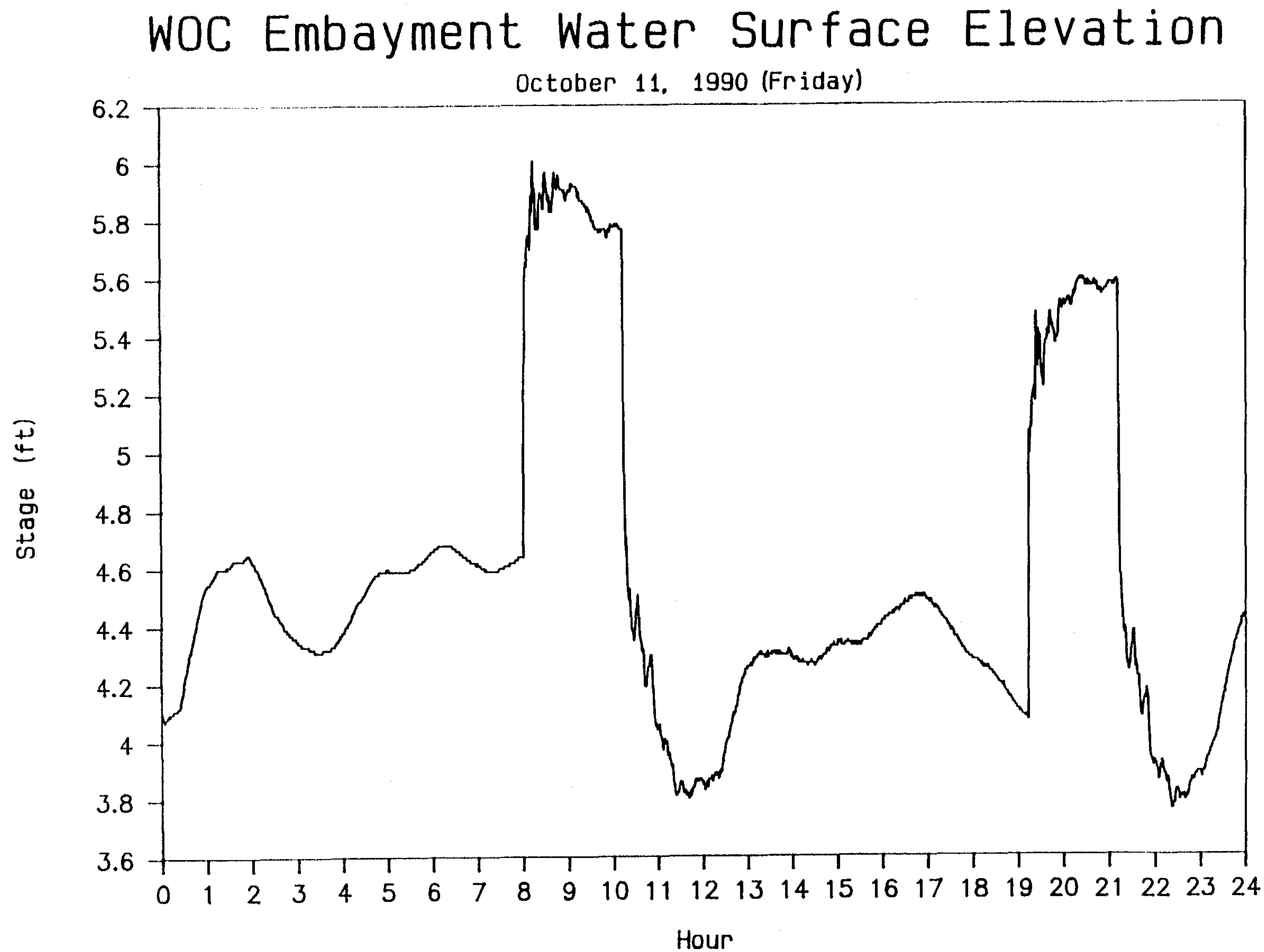

Fig. 9. Water surface elevation at the mouth of the Whiteoak Creek embayment on October 11, 1990.

ORNL DWG 91-14920

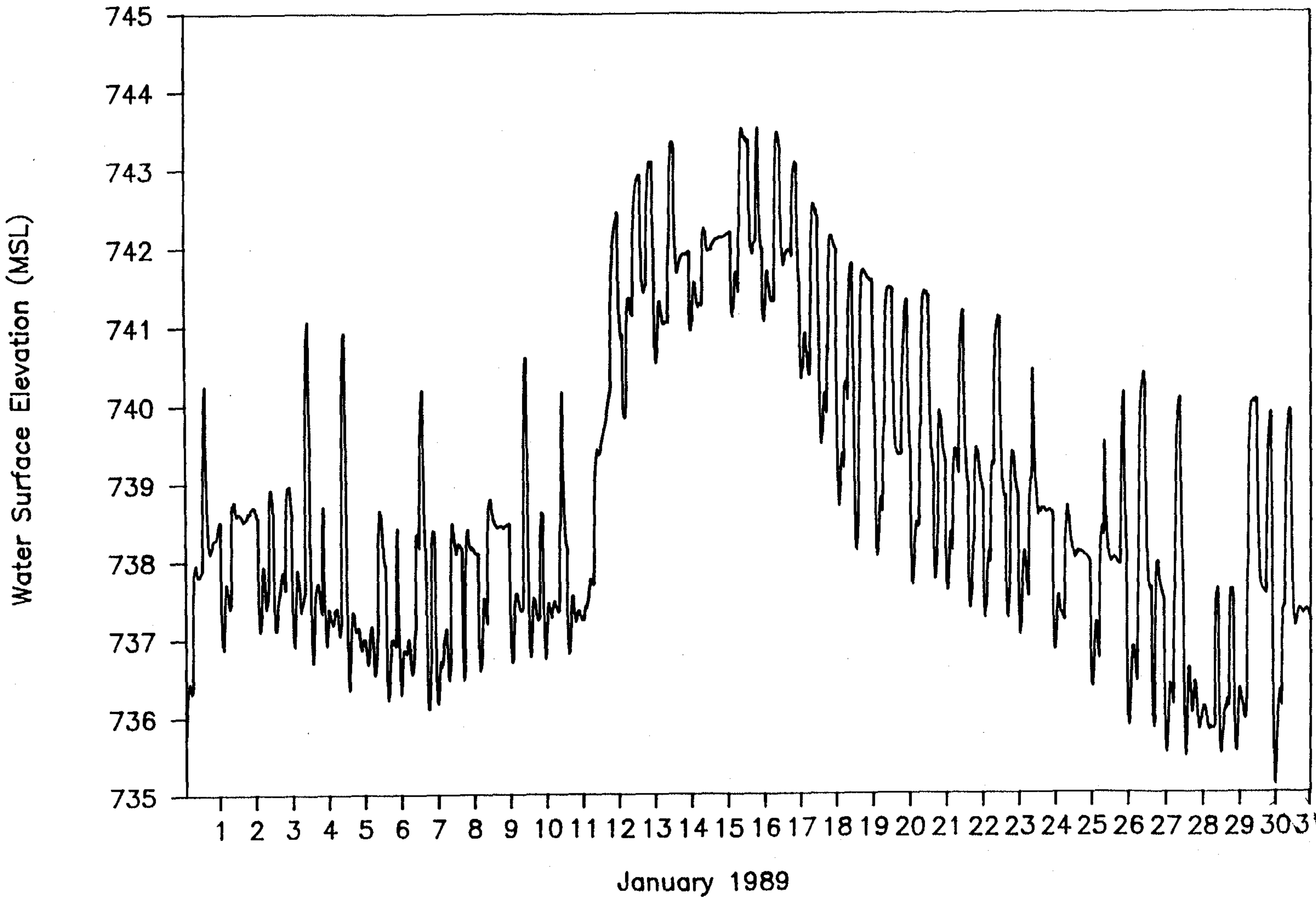

Fig. 10. Trends in the water surface elevation at the mouth of the Whiteoak Creek embayment in a wet winter month, January 1989.

2.4 SOILS

The soils of Roane County were mapped in the 1930s and the results were published in 1942 (Swann et al. 1942). Tschantz and Rghebi (1989) analyzed soil survey maps of Roane and Anderson County and identified approximately forty different soil groups in the WOC watershed (Table 3). The soils, most of silty or very fine loam texture, fall into three major hydrologic soil groups (HSGs): B, C, and D, and range from moderate, slow, to very slow infiltration rates, respectively.

Soils in the watershed are clustered into six broad bands running east to west (ORNL grid) as shown in Fig. 11. Soils are distributed in the watershed as follows: 54.1% of the watershed area is HSG B, 20.0% is HSG C, and 25.9% is HSG D. Therefore, the natural soils of the watershed, in both Bethel and Melton Valleys, have relatively slow infiltration rates and tend to yield relatively high runoff.

2.5 CONTAMINANTS IN WOC WATERSHED

Water in WOL contains measurable quantities of dissolved ^{3}H and ^{90}Sr, which are released through the monitoring station at WOD. Controlled releases of ORNL treated and untreated effluents to WOC include those from the Process Waste Treatment Plant (PWTP), the Sewage Treatment Plant (STP), and a variety of process waste holding ponds scattered throughout the ORNL complex. The WOC flow system also receives effluent through both surface and groundwater flow from nonpoint sources, the SWSAs and LLW pits and trenches (Fig. 11). Sediments within the WOC flow system have sorbed chemical and radioactive contaminants and have accumulated in the WOC floodplain and WOL. Oakes et al. (1982) estimated that approximately 5×10^{6} ft^{3} of contaminated sediment had collected in the lake bed since 1943. The sediment in the lake bed contains an estimated 650 Ci of radioactive isotopes, primarily ^{137}Cs, ^{60}Co, and ^{90}Sr. During periods of heavy runoff, both dissolved radionuclides and resuspended, contaminated sediment (Sects. 3.2.2 and 3.2.3) are released from the lake into the Clinch River.

Table 3. Whiteoak Creek Watershed hydrologic soil groups

COUNTY	SOIL GROUP DESCRIPTION	HSG CODE	COUNTY	SOIL GROUP DESCRIPTION	HSG CODE
Roane	Armuchee silt loam	D	Roane	Lindside silt loam	C
	Pope very fine sandy loam	B		Colbert silt loam	D
	Philo very fine sandy loam	B		Fullerton cherty silt loam	B
	Colbert silty clay loam	D		Melvin silt loam	D
	Apison very fine sandy loam	B		Fullerton cherty silt loam	B
	Pope gravelly fine sandy loam	B		Talbott silty clay loam	C
	Lehew stony fine sandy loam	C		Talbott stony material	C
	Gullied land-Apison soil	B		Fullerton-rough gullied	B
	Colbert silt loam	D		Roane gravelly loam	B
	Clarksville cherty silt loam	B		Dewey silty clay loam	B
	Fullerton cherty silt loam	B		Dewey silt loam	B
	Fullerton cherty silt loam	B		Dewey silty clay loam	B
	Fullerton cherty silt loam	B		Fullerton cherty silt loam	B
	Upshur silty clay loam	C		Dewey silty clay loam	B
	Stony land-Colbert/Talbott	D/C	Anderson	Fullerton cherty silt loam	B
	Talbott silty clay loam	C		Minvale cherty silt loam	B
	Clarksville cherty silt loam	B		Bodine cherty silt loam	B
	Clarksville cherty silt loam	B		Fullerton cherty silt loam	B
	Apison very fine sandy loam	B		Greendale silt loam	B
				Fullerton cherty silt loam	B

ORNL DWG 90M 16668

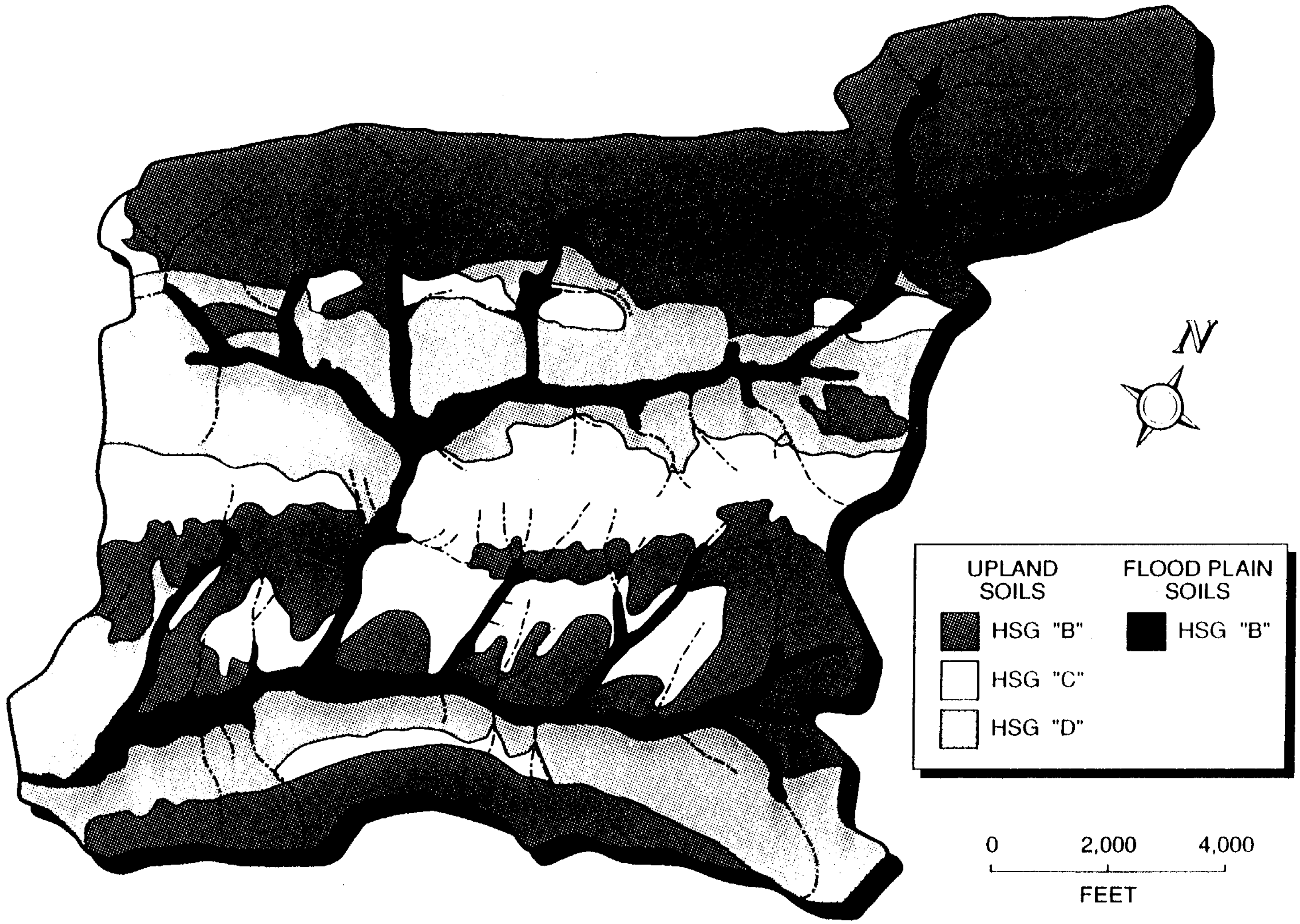

Fig. 11. Whiteoak Creek watershed soils classified according to hydrologic groups (HSGs). See Table 3 for soil series and HSGs. The HSG B soils class has been separated into upland and floodplain soils.

3. HYDROLOGIC DATA

The collection of hydrologic data in the WOC watershed began with facility planning studies in the early 1940s. Collection of these data has developed into a long-term program of environmental research studies and monitoring activities required to cope with the Laboratory's unique waste management needs.

The hydrologic data available for the report period were derived largely from ongoing studies of the ORNL Environmental Restoration program (ERP) and, to a lesser extent, from the continuing effluent and environmental surveillance monitoring conducted by the ORNL Environmental Surveillance and Protection (ESP) Section of the Office of Environmental and Health Protection (OEHP). Much of this monitoring is associated with the National Pollutant Discharge Elimination System (NPDES) permit for ORNL operations (EPA 1986). The following section provide information on hydrologic data available in the RAP data and information system, and elsewhere, and data summaries for selected stations.

3.1 CLIMATE

Precipitation, temperature, humidity, wind speed, and wind direction data are available for several stations located in the vicinity of the WOC watershed (Table 4). The period of record varies from station to station. The National Oceanic and Atmospheric Administration Atmospheric Turbulence and Diffusion Laboratory (NOAA/ATDD) monitoring station located in Oak Ridge about 15.4 km (9.6 miles) north of the center of the watershed is the closest long-term meteorological station, with records dating from 1947.

Precipitation is probably the most important climatic factor in hydrologic studies, since it establishes quantity and variations in runoff and streamflow. It also replenishes groundwater. Maximum, mean, and minimum annual precipitation for stations near ORNL during the period 1954–1983 was 190.0, 132.6, and 89.7 cm (74.8, 52.2, and 35.3 in), respectively (Webster and Bradley 1989). Monthly precipitation at the NOAA/ATDD station generally ranges from 13.46–15.75 cm (5.3–6.2 in) during the wettest months (January–March), and from 7.37–9.65 cm (2.9–3.8 in) during the driest months (August–October) (NOAA 1974). Table 5 shows the frequency of occurrence for precipitation at various intensities over periods of 5 minutes to 24 hours (Huff and Frederick 1984). The mean annual runoff for streams in the ORNL area is 56.6 cm (22.3 in)(McMaster 1967). The remainder of the mean annual precipitation, about 76.2 cm (30 in), is consumed by evapotranspiration.

Figure 12 shows meteorological stations for which data are available in the RAP data base management system and Table 6 contains site descriptions and information on data collection methodology.

Table 7 displays monthly precipitation for Water Year 1990 at sites in the vicinity of the WOC watershed and at the NOAA/ATDD station in Oak Ridge. It also gives the normal

Table 4. Meteorological stations in the vicinity of the WOC watershed[a] Adapted from Boegly et al. 1985

STATION DESCRIPTION	LOCATION	PERIOD OF RECORD	MEASUREMENTS
Knoxville (TYS)[b]	McGhee Tyson Airport	1942–Present	Precipitation, wind, temperature, temperature gradient, and humidity
Oak Ridge (ATDD)	City	(a) 1947–Present (b) 1947–1979	(a) Precipitation, temperature, and temperature gradient; (b) Wind
First Creek (1st CR)	ORNL	1987–Present	Precipitation
USGS 7500 Bridge (7500B)	7500 Bridge	1987–Present	Precipitation
ETF	SWSA 6	1980–Present	Precipitation[c]
TR7	Trench 7	1985–1987	Precipitation
SW7	SWSA 7	1984–Present	Precipitation

[a]Meteorological measurements have been made at the Y-12 Plant, K-25 Plant, an early ORNL station, and the Tower Sheilding Facility at various times.
[b]Measurements also exist for the period 1871 until the station was moved to McGhee Tyson Airport.
[c]Precipitation gages are not equipped to measure snowfall.
[d]Ion exchange resin leaching site.

Table 5. Rainfall vs frequency for areas up to 25.9 km^2 (10 mi^2) in Anderson and Knox counties, Tennessee
Adapted from Huff and Frederick 1984
Units=mm

DURATION FREQUENCY (years)	MINUTES[b]					HOURS[c]				
	5	10	15	30	60	2	3	6	12	24
2	10.9	16.5	20.3	29.0	38.1	45.7	50.8	61.0	71.1	83.8
5	12.7	19.8	24.9	35.3	47.3	61.0	53.5	76.2	91.4	106.7
10	14.2	22.6	28.5	41.9	55.9	68.6	73.7	88.9	104.1	121.9
25	16.3	26.2	33.0	48.0	53.5	76.2	86.4	99.1	119.4	139.7
50	18.0	29.2	36.8	53.6	71.1	86.4	94.0	119.4	134.6	154.9
100	19.6	32.0	40.6	59.9	78.7	96.5	101.6	124.5	144.8	167.6
Probable maximum, 6-h duration: 723.9										

[a]1 mm = 0.04 in.

[b]2-, 100-year and 5-, 15-, and 60-min data are from maps in NWS HYDRO-35 (Frederick et al. 1977). All other "minute" data are calculated using appropriate equations from the same publication. These equations are:

10 min: (0.59)(15 min) + (0.41)(5 min)
30 min: (0.49)(60 min) + (0.51)(15 min)

5 year: (0.278)(100 year) + (0.674)(2 year)
10 year: (0.449)(100 year) + (0.496)(2 year)
25 year: (0.669)(100 year) + (0.293)(2 year)
50 year: (0.835)(100 year) + (0.146)(2 year)

[c]Interpolated from maps in USWB TP 40 (Hershfield 1961).

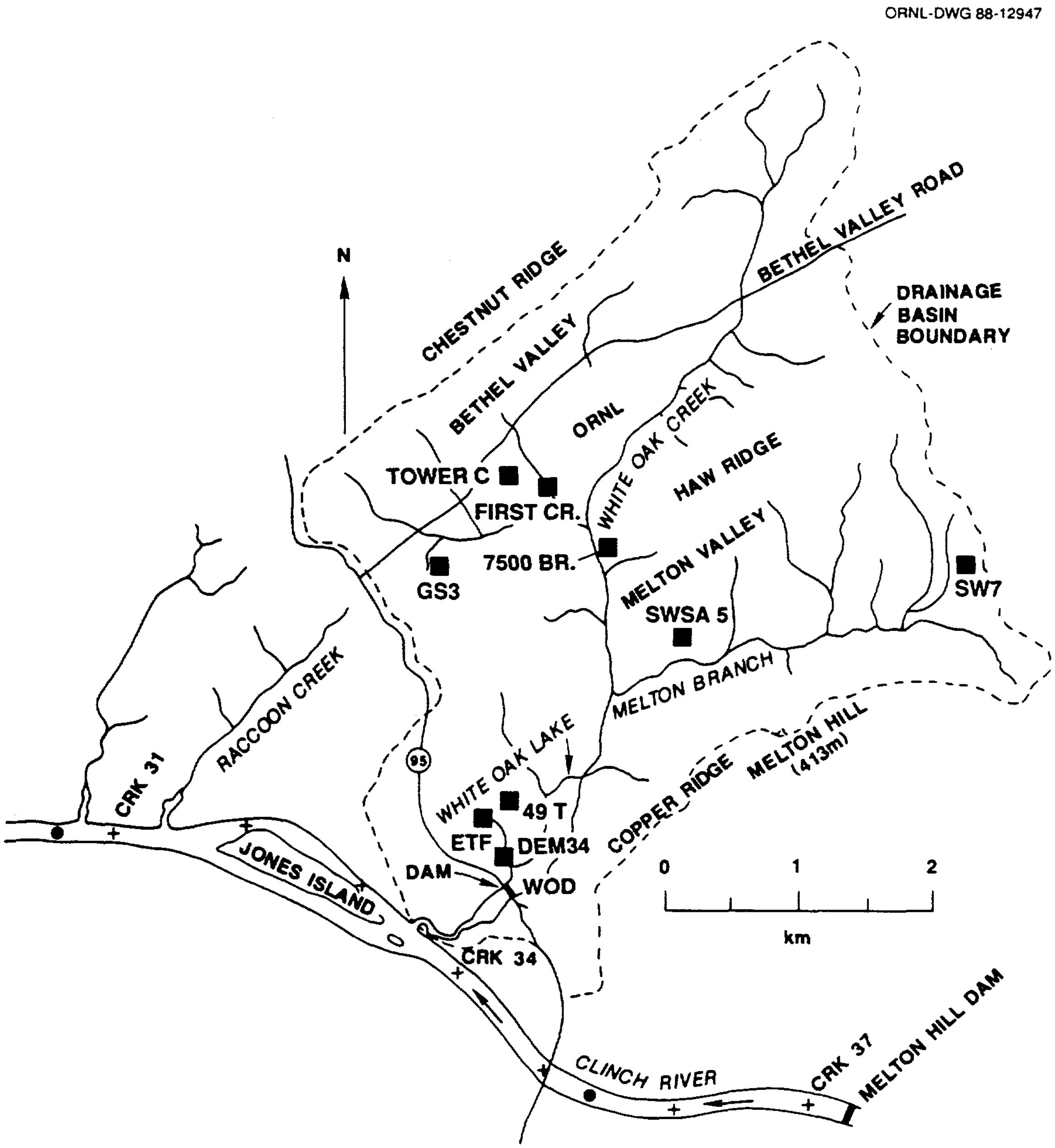

Fig. 12. Meteorological stations in the Whiteoak Creek watershed for which data are available through the RAP data base system.

Table 6. Precipitation measurement descriptions for stations located in the WOC watershed and the NOAA/ATDD Oak Ridge station

STATION DESCRIPTION	TYPE OF GAGE	FREQUENCY OF DATA COLLECTION	SMALLEST UNIT OF MEASURE FOR GAGE (in)
Oak Ridge (ATDD)	Belfort Weight & Stick	Hourly	0.01
First Creek (1st CR)	Belfort Weighing	Daily	0.01
USGS 7500 Bridge (7500B)	Electric Tipping Bucket	Daily	0.01
ETF	Belfort Weighing	Daily	0.01
TR7	Belfort Weighing	Daily	0.01
SW7	Belfort Weighing	Daily	0.01

Table 7. Monthly precipitation totals at the WOC watershed and NOAA/ATDD stations during water year 1990
Units=mm

DATE	7500B	1ST CR	ETF	SW7	49T	ATDD Actual	ATDD Normal
October 1989	43.3	59.6	64.9	51.7	61.1	62.5	69.1
November 1989	132.6	144.1	143.4	130.7	137.7	153.9	102.9
December 1989	69.6	44.0	46.0	43.8	72.6	49.3	136.1
January 1990	134.6	140.7	142.0	136.1	135.4	134.4	133.4
February 1990	166.3	190.8	197.1	182.4	183.9	203.5	133.1
March 1990	108.5	119.9	124.5	125.2	118.6	124.2	138.4
April 1990	55.6	63.5	60.5	74.7	66.3	65.3	106.9
May 1990	188.5	198.9	194.8	190.0	190.3	167.4	89.4
June 1990	38.6	42.7	64.8	42.4	61.5	38.9	100.1
July 1990	168.2	206.0	182.9	187.2	188.2	128.5	144.0
August 1990	119.1	165.4	143.3	144.8	142.2	129.3	97.8
September 1990	22.2	35.8	42.7	41.9	38.4	36.6	84.8
TOTAL (mm)	1247.1	1411.2	1406.7	1350.9	1396.1	1293.7	1336.1
TOTAL (in)	49.1	55.6	55.4	53.2	55.0	50.9	52.6

(mean) precipitation (52.6 in), based on the 30-year (1951–1980) period of record, for the NOAA/ATDD station. Daily precipitation at these sites is shown in Appendix A.

The current reporting period (Water Year 1990) is during the second year of a period of recovery from the previous four-year drought. The four-year drought period (~1985–1988) saw a cumulative precipitation deficit of 112.8 cm (44.42 in). In Water Year 1989, eight of the twelve months had above average precipitation, including June 1989 which set a June record high with 28.3 cm (11.14 in) at the NOAA/ATDD station. Previous reporting periods (previous annual reports) were during the aforementioned four-year drought. In 1985, annual (calendar year) precipitation measured at the NOAA/ATDD station was 118.2 cm (46.54 in), 85% of normal for the 30-year period of record. In 1986, annual precipitation was 98.6 cm (38.82 in), 71% of normal. In 1987, annual precipitation at the station was 102.4 cm (40.31 in), 74% of normal, while annual precipitation in 1988 was 124.3 cm (48.95 in) (89% of normal). In 1989, there was 167.7 cm (66.01 in), 121% of normal and in 1990 there was 151.8 cm (59.78 in), 109% of normal, precipitation. Table 7 shows precipitation at the NOAA/ATDD station was below average for seven months and above average for five months of the current reporting period, resulting in a near normal year with a deficiency of approximately 6.4 cm (2.5 in) for the 12-month period. Figures 13 and 14 compare the annual plots (hyetographs) of daily precipitation at the ETF raingage in the WOC watershed with the NOAA/ATDD station in Oak Ridge.

3.2 SURFACE WATER

Data on surface-water discharge and quality are collected at several sites in the WOC flow system from numerous studies conducted (a) by the ERP, (b) as part of the ESP monitoring and compliance program associated with the NPDES permit, (c) from numerous ESD research projects, (d) from evaluations by the Interim Waste Operations group, and (e) in a number of independent studies. Some water quality data are also collected periodically as part of the BMAP, which is required by the NPDES permit (Loar 1990).

3.2.1 Discharge

Data on streamflow in the vicinity of the WOC watershed are collected by ESD, the USGS, and ESP. Daily streamflow data collected at 22 sites (Fig. 15) in the WOC system are available in the ORNL RAP Data and Information Management System (DIMS) consolidated data base. Three sites, WOD, WOC, and Melton Branch (MB) are operated by ESP as part of the NPDES permit requirements, and 8 sites are currently operated by the U.S. Geological Survey (USGS) as a component of ERP studies to isolate individual contributions from upstream hydrologic units and for application in modeling studies. An additional ESP site (WOC Headwaters monitoring station) has been established on WOC, upstream of all ORNL facility effluents and Bethel Valley Road, to monitor background water quality and flow in the headwaters area. Data collection activities at this site began in November 1988.

Stream discharge data are also being collected by ESD's Watershed Hydrology Group at 10 sites. These sites are monitored simultaneously at the four ESP stations (above) and at the USGS station on Center Seven Creek (which includes an independent low-flow control and sensor for better resolution of dry weather base flows), and discharge at five additional

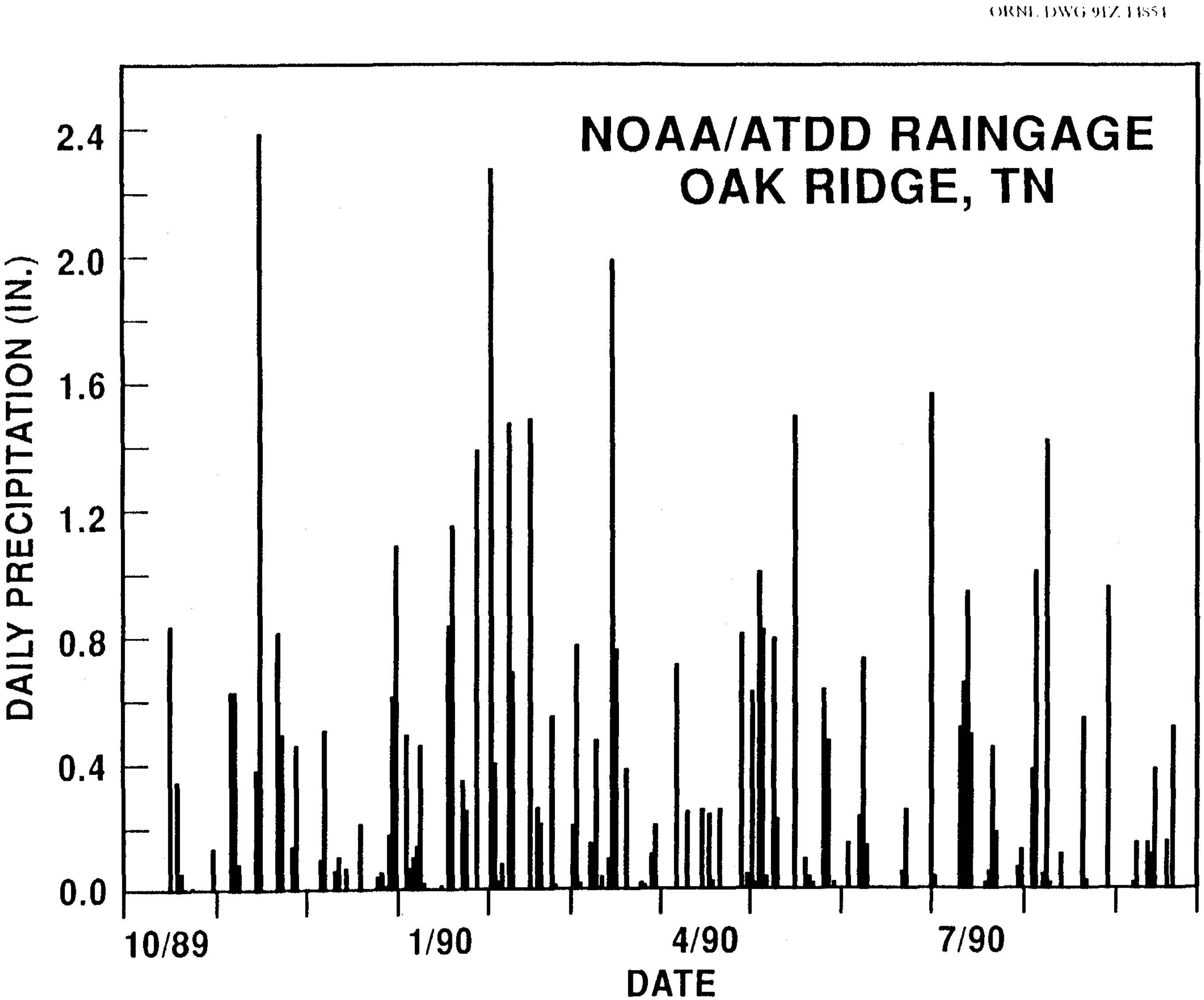

Fig. 13. Daily precipitation measured at the NOAA/ATDD raingage in Oak Ridge in Water Year 1990.

ORNL DWG 91Z 1855

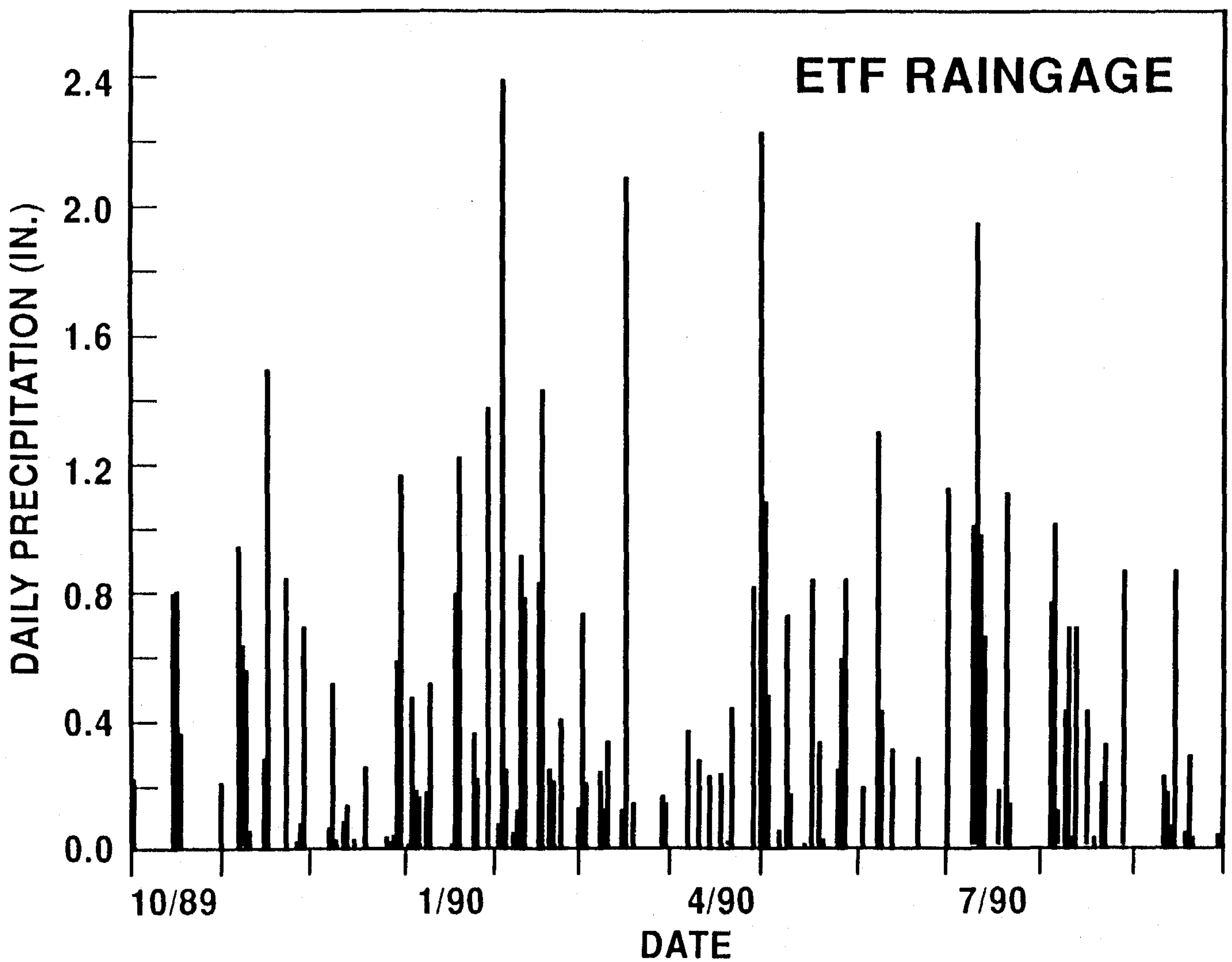

Fig. 14. Daily precipitation measured at the ETF raingage in the Whiteoak Creek watershed in Water Year 1990.

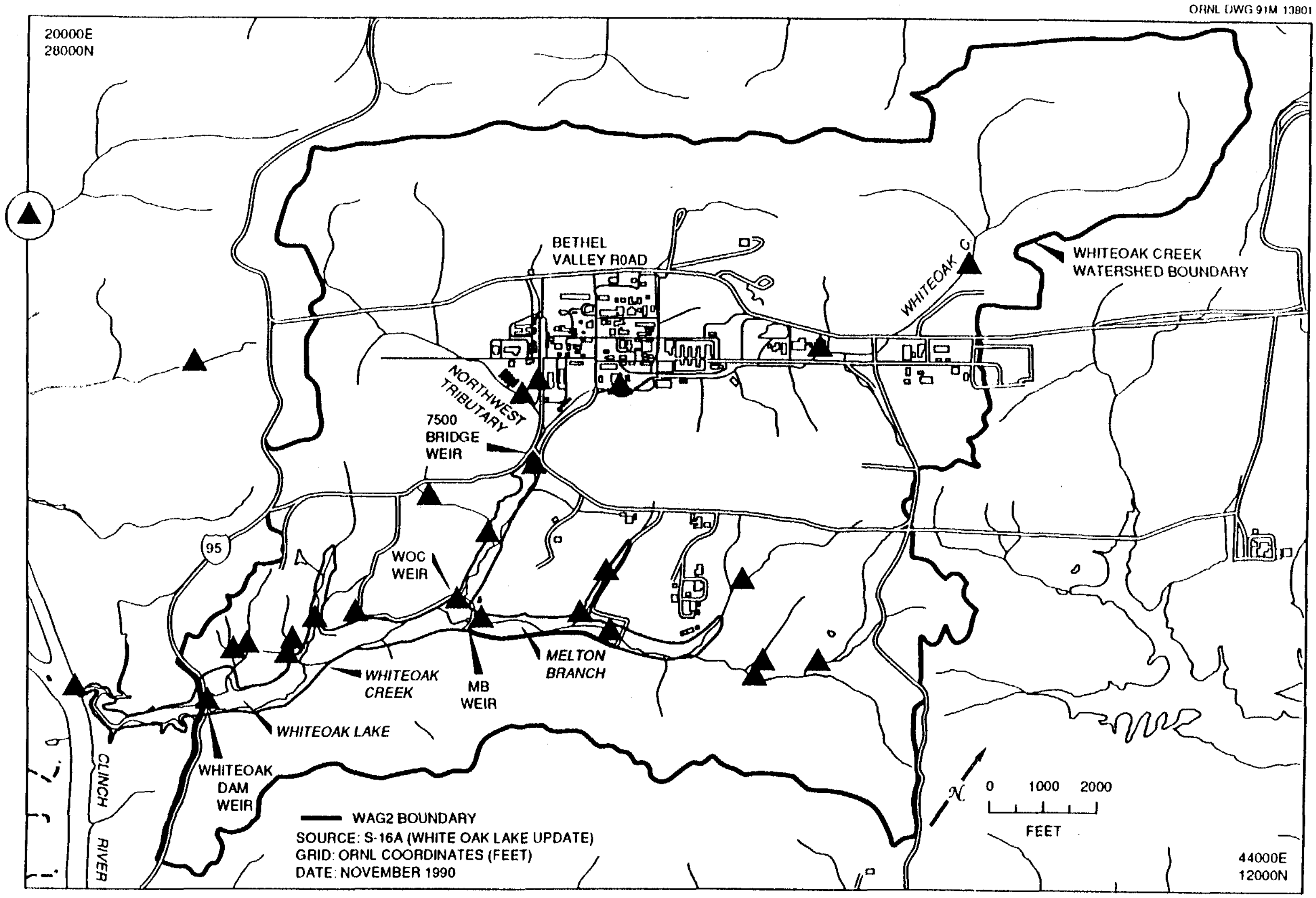

Fig. 15. Locations of surface water discharge monitoring stations in the Whiteoak Creek watershed.

surface water monitoring stations are monitored independently. These include two sites (East and West Seeps) on tributaries that drain the pits and trenches area (WAG 7) northeast of WOL, one site (MS1) that drains SWSA 4 to the south into WOC, and two sites (Ish and Raccoon Creeks) located outside the WOC watershed, west of State Highway 95. Figures 16-18 show discharge hydrographs for the three major monitoring stations on WOC (MS3), MB (MS4), and WOD (MS5) for Water Year 1990.

In Water Year 1990, streamflow data were collected at 17 monitoring stations near WOC watershed (Figure 15). In addition to measurements taken at these 17 stations, measurements of stage-height were made at the mouth of WOC on the Clinch River. In the WOC watershed, there are at least nine more streamflow monitoring stations, outfitted with at least a hydraulic control device. These devices are in various states of repair, but they could be upgraded and instrumented to collect streamflow data.

Physical descriptions and monitoring status information on both operating and non-operating stations have been summarized. The increasing emphasis on characterizing and quantifying discharge from contaminated areas could affect decisions on upgrading the non-operating stations.

1. Whiteoak Dam (WOD, X15, MS5)

   Physical description: Station is at the outfall of Whiteoak Lake (WOL) where Whiteoak Creek (WOC) flows under State Highway 95, 1 km (0.6 mi) above the confluence with the Clinch River. Waters impounded by Whiteoak Dam (WOD) flow through two 5.5 m (18 ft) sluice gates, through a 12.2 m (40 ft) wide channel; across a triangular, concrete, broad-crested weir (high-flow control); and finally, across a stainless steel, sharp-crested Cipoletti (trapezoidal) weir (low-flow control) before spilling into the Whiteoak Creek embayment. The notch (crest) elevations on the broad- and sharp-crested weirs are about 226.8 m (744.0 ft) and 226.6 m (743.5 ft) above mean sea level (MSL), respectively. Normal pool elevation for WOL is about 227.1 (745 ft) MSL. Maximum lake elevation (without overtopping the gates) with the gates closed is about 228.6 m (750 ft) MSL. Crest elevation of WOD is about 230.13 m (755.05) ft MSL at its lowest point near the longitudinal center (Tschantz, 1987).

   Monitoring status: ESP collects hourly and daily (totalizer) discharge data by ultrasonic flow meters for compliance purposes. ESD's Hydrology Group collects stage height data at four sensor locations, including lake level, for conversion to discharge data.

2. Whiteoak Creek (WOC, X14, MS3)

   Physical description: Station is on WOC above the confluence with MB. Water flows into a stilling pool impounded by a concrete sill; through twin stainless steel, sharp-crested, 100° V-notch weirs contained in the sill; into a 11.0 m (36 ft) wide channel; then across a rectangular, concrete, broad-crested weir before finally spilling back into the natural channel downstream from the station. The elevations of the top of the V-notch weirs, the crests of the V-notch weirs, and the broad-crested weir are about 230.21 m, 229.45 m, and 229.21 m (755.31, 752.81, and 752.05 ft) MSL, respectively.

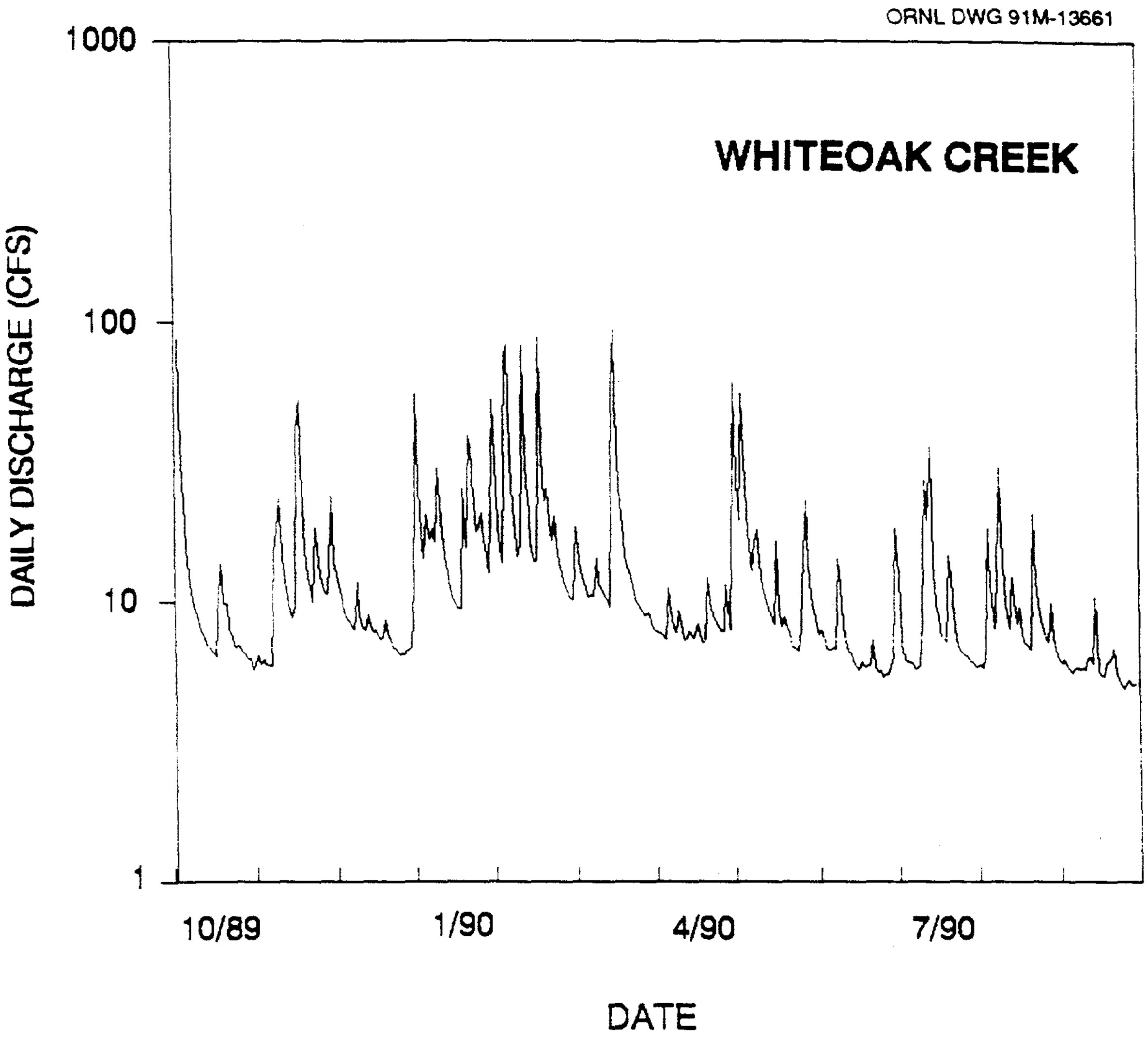

Fig. 16. Daily streamflow in Water Year 1990 at the Whiteoak Creek monitoring station.

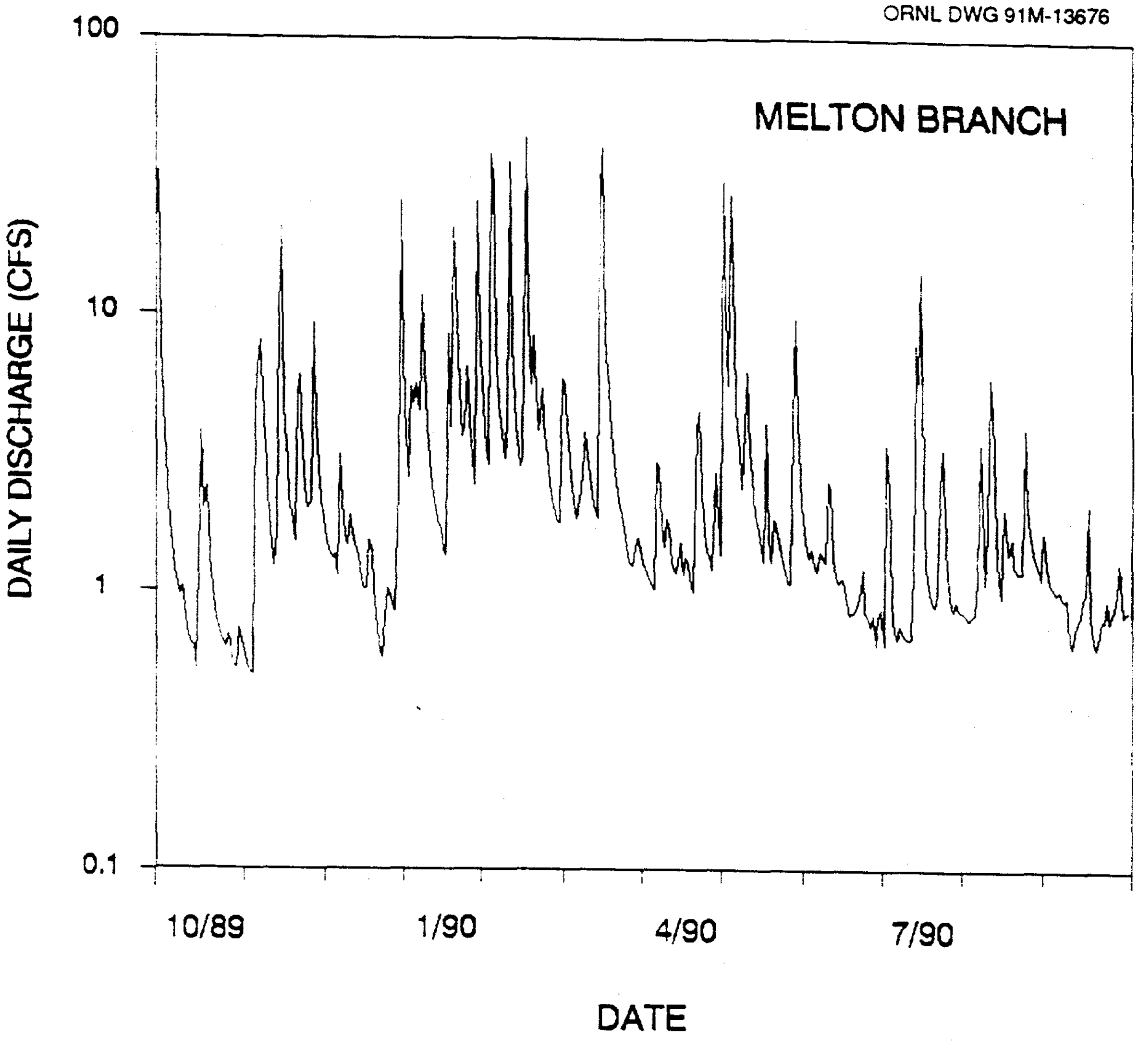

Fig. 17. Daily streamflow in Water Year 1990 at the Melton Branch monitoring station.

ORNL DWG 91-14917

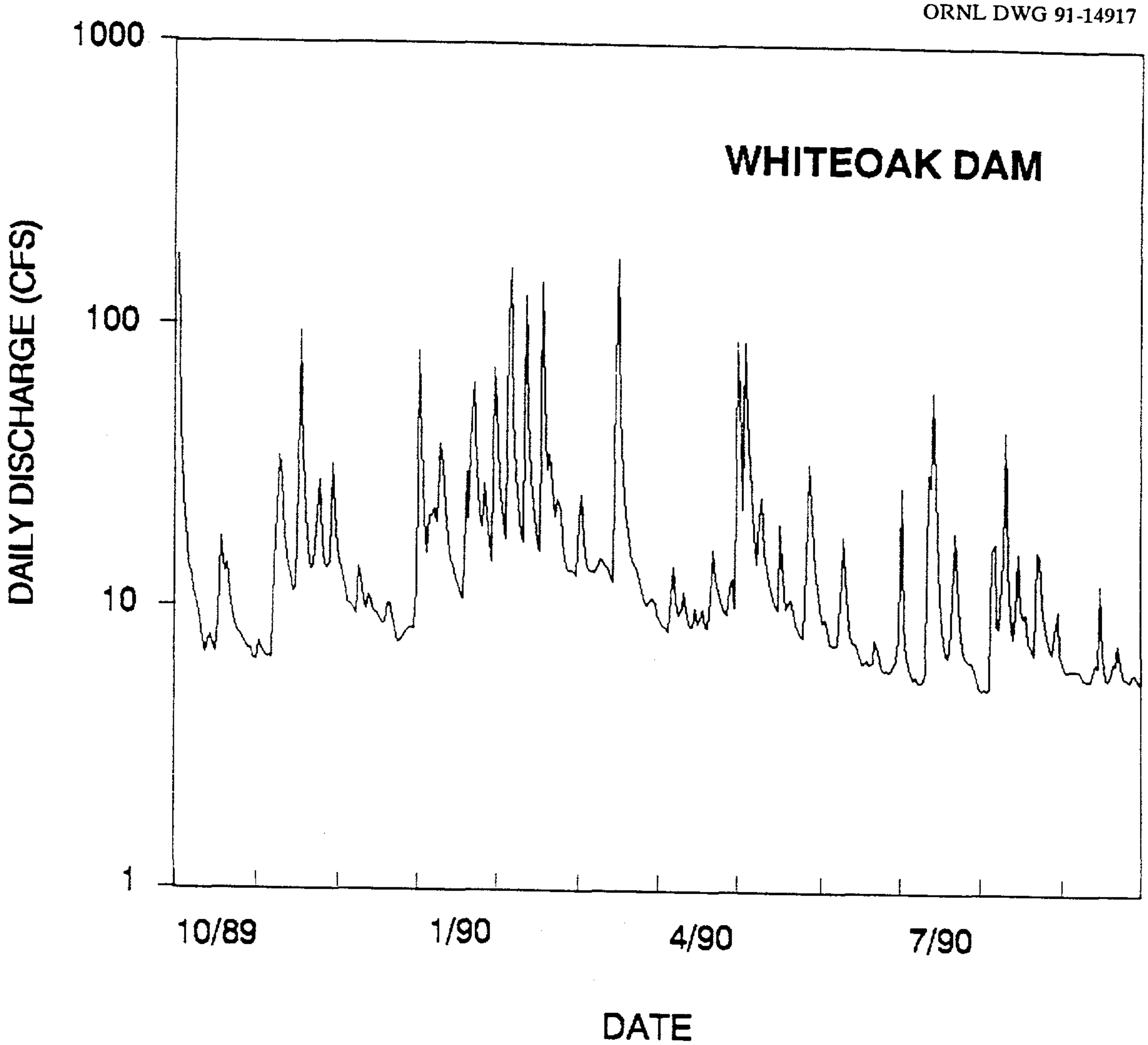

Fig. 18. Daily streamflow in Water Year 1990 at the Whiteoak Dam monitoring station.

Monitoring status: ESP collects hourly and daily (totalizer) discharge data by ultrasonic flow meters for compliance purposes. ESD's Hydrology Group collects stage height data at three sensor locations for conversion to discharge data.

3. Melton Branch (MB, X13, MS4)

   Physical description: Station is on MB above the confluence with WOC. Water flows into a stilling pool impounded by a concrete sill, through a stainless steel, sharp-crested, 120° V-notch weir contained in the sill; into a 7.3 m (24 ft) wide channel; then across a rectangular, concrete, broad-crested weir before finally spilling into a tailwater pool downstream from the station. The elevations of the top of the V-notch weir, the crests of the V-notch weir, and the broad-crested weir are about 230.3 m, 229.6 m, and 229 m (755.60, 753.35, and 751.43 ft) MSL, respectively.

   Monitoring status: ESP collects hourly and daily (totalizer) discharge data by ultrasonic flow meters for compliance purposes. ESD's Hydrology Group collects stage height data at three sensor locations for conversion to discharge data.

4. Whiteoak Creek Headwaters (WOCHW)

   Physical description: Station is in the upper reaches of WOC, north of Bethel Valley Road and upstream from any ORNL facility discharges. Therefore, this station is considered a background monitoring station for WOC. The control device is a compound, stainless steel, critical-flow flume.

   Monitoring status: ESD's Hydrology Group operates electronic and mechanical data loggers; maintains instrumentation; collects punch-tapes and electronic data storage packs; processes tapes and storage packs; and generates, verifies, and stores discharge data. ESP operates a flow totalizer at this station.

5. East Seep

   Physical description: Station is in WAG 7 on the east seep tributary to the headwaters of WOL. The control device is a stainless steel, sharp-crested, 90° V-notch weir.

   Monitoring status: Instrumentation includes a Stevens model 7001 float-type gage housed over a stilling well and equipped with a digital punch, stage-height recorder. ESD's Watershed Hydrology Group maintains instrumentation; collects punch tapes; processes the tapes; and generates, verifies, and stores discharge data.

6. West Seep

   Physical description: Station is in WAG 2 bordering the east slope of WAG 6 on the west seep tributary to the headwaters of WOL. The control device is a compound, stainless steel, sharp-crested, weir consisting of a 120° V-notch, low-flow section and a rectangular, high-flow section.

Monitoring status: Instrumentation includes a Stevens model 7001 float-type gage housed over a stilling well and equipped with a digital punch, stage-height recorder. ESD's Watershed Hydrology Group maintains instrumentation; collects punch tapes; processes the tapes; and generates, verifies, and stores discharge data.

7. WAG4-2 (MS1)

Physical description: Station is on the upper reaches of an unnamed tributary to Whiteoak Creek that runs along the southern boundary of SWSA 4. Access to the site is through SWSA 4 from Lagoon Road. The control device is a Plasti-fab, prefabricated fiberglass, 5 cm (2 in), 45° trapezoidal flume.

Monitoring status: Instrumentation includes an Omnidata Easy Logger (electronic data logger) with a submerged pressure transducer installed in the stilling pool for measuring stage. ESD's Watershed Hydrology Group maintains instrumentation; retrieves data storage packs; downloads and processes the data; and generates, verifies, and stores discharge data.

8. Ish Creek

Physical description: Station is at the bridge on New Zion Patrol Road, 2.7 km (1.7 mi) west of State Highway 95 and 0.6 km (0.4 mi) upstream from the mouth at Clinch River kilometer 30.7 (mile 19.1). The low-flow control device is a stainless steel, critical flow flume, and the high-flow control device is the rectangular, concrete, culvert (bridge) opening.

Monitoring status: Instrumentation includes a Stevens model 7001 float-type gage housed over a stilling well and equipped with a digital punch, stage-height recorder. ESD's Watershed Hydrology Group maintains instrumentation; collects punch tapes; processes the tapes; and generates, verifies, and stores discharge data.

9. Raccoon Creek

Physical description: Station is in the upper reaches of Raccoon Creek, approximately 0.4 km (0.25 mi) west of State Highway 95, 0.15 km (0.1 mi) south of New Zion Patrol Road, and 2.1 km (1.3 mi) upstream from the mouth at Clinch River kilometer 31.5 (mile 19.5). The control device is a stainless steel, sharp-crested weir in three sections: a 56° V-notch in the center of the channel for stages from 0 to 1.25 ft; and a vertical extension of the V-notch and two rectangular weir plates with end contractions, one on each side of the V-notch, for stages from 1.25 to 2.5 ft.

Monitoring status: Instrumentation includes a Stevens model 7001 float-type gage housed over a stilling well and equipped with a digital punch stage-height recorder. ESD's Watershed Hydrology Group maintains instrumentation; collects punch tapes; processes the tapes; and generates, verifies, and stores discharge data.

10. WAG 6 Tributaries (FA, FB, DA, and DB)

    Physical description: Stations are on the four drainages in WAG 6 (all draining into Whiteoak Lake). Proceeding west to east: station FA is a 5 cm (2 in), 60° trapezoidal flume; station FB is a 15 cm (6 in) parshall flume; station DA is a 0.46 m (18 in) parshall flume; and station DB consists of 15 cm and 0.91 m (6 in and 36 in) parshall flumes in series. All flumes are prefabricated fiberglass flumes with dual 0.3 m (12 in) stilling wells for upstream (H1) and downstream (H2) head measurements.

    Monitoring status: Currently not instrumented. ESD's Watershed Hydrology Group collected data at all four stations for a brief period, from about late April to early June of 1990. All four stations are to be reinstrumented for discharge data collection in the summer of 1991 as part of the ASEMP.

11. Melton Branch Tributary (HRTF)

    Physical description: Station is on the tributary to Melton Branch in the vicinity of the old Homogenous Reactor Test Facility upstream from the confluence with MB and downstream from station HRT (#8 above). The control device is a Manning 0.46 m (18 in), prefabricated fiberglass Palmer-Bowlus flume.

    Monitoring status: No monitoring is conducted at this station. Some limited stage data were collected by ESD from about August 1989 to January 1990 for an independent study on storm-flow sampling. These data are available in electronic files but have not been processed.

12. WAG4-2A (T-2A)

    Physical description: Station is just above the mouth of an unnamed tributary to Whiteoak Creek that runs along the southern boundary of SWSA 4 in the vicinity of the old intermediate detention pond. The control device is a Plasti-Fab prefabricated fiberglass, 12.7 cm (5 in), 45° trapezoidal flume.

    Monitoring status: Currently not instrumented. ESD collected stage-height data from approximately 10/83 through 1/89.

13. Melton Branch (MB2)

    Physical description: Station is on MB upstream from the confluence with the HRT (Homogenous Rector Test Facility) tributary. The control device is a 1.83 m (6 ft) wide, stainless steel, sharp-crested, trapezoidal weir.

    Monitoring status: ESP operates a flow totalizer at this station.

14. Melton Branch Tributary (HRT, HRE)

<u>Physical description</u>: Station is on the tributary to MB in the vicinity of the old Homogenous Reactor Test Facility. The control device is a stainless steel, sharp-crested, 90° V-notch weir.

<u>Monitoring status</u>: No monitoring is conducted at this station. ESP has monitoring equipment (flow totalizer, samplers, etc.) available on-site in an instrument enclosure.

15. Whiteoak Creek and Clinch River Confluence (WOCCON)

<u>Physical description</u>: Station is at the mouth of WOC on the Clinch River at Clinch River mile 20.8. Station is a stage recorder only (no control device).

<u>Monitoring status</u>: ESD's Watershed Hydrology Group installed an electronic data logger and a submerged pressure transducer in September 1988 to record stages at 15 min. intervals. This station was temporarily dismantled in January 1991 to make way for a permeable dam to be constructed at the mouth of WOC. The Off-Site ERP planned to reinstall a stage-height recorder in the summer of 1991.

16. Upper Whiteoak Creek (GS6, USGS #03536320)

<u>Physical description</u>: Station is on WOC east of the east gate outside the main plant area and north of the point where WOC crosses Whiteoak Avenue, near Building 6000, ORNL. The control is a natural bedrock outcropping in the stream.

<u>Monitoring status</u>: The USGS instrumentation includes a Stevens model 7001 float-type gage housed in an instrument shelter over a stilling well on the right bank of the stream. The gage is equipped with a digital punch, stage-height recorder that collects raw stage data at 15-min intervals for conversion to hourly average discharge values.

17. Whiteoak Creek Parshall Flume (GS5, USGS #03536380)

<u>Physical description</u>: Station is at the existing MS2 concrete and stainless steel, parshall flume on WOC in the main plant area downstream from the confluence with Fifth Creek and upstream from the STP outfall.

<u>Monitoring status</u>: USGS instrumentation includes a Stevens model 7001 float-type gage housed over a stilling well and mounted at the upstream side of the concrete structure containing the flume, near the left bank. The gage is equipped with a digital punch, stage-height recorder that collects raw stage data at 15-min intervals for conversion to hourly average discharge values.

18. Northwest Tributary (NWT, GS4, USGS #03536440)

<u>Physical description</u>: Station is on the Northwest tributary to WOC above the confluence with First Creek, southwest of the fish ponds behind Building 1504, ORNL. The control device is a concrete and stainless steel, short-crested triangular weir.

Monitoring status: USGS instrumentation includes a bubbler gage equipped with a digital punch, stage-height recorder. The gage collects raw stage data at 15-min intervals for conversion to hourly average discharge values. ESP operates a flow totalizer at this station.

19. First Creek (GS1, USGS #03536450)

Physical description: Station is on the First Creek tributary to WOC (above) between Burial Ground Road and the confluence with the Northwest tributary. The control device is a compound, stainless steel, critical-flow flume.

Monitoring status: USGS instrumentation includes a Stevens model 7001 float-type gage housed over a stilling well and equipped with a digital punch, stage-height recorder. The gage collects raw stage data at 5-min intervals for conversion to hourly average discharge values.

20. 7500 Bridge (MS2A, GS3, USGS #03536550)

Physical description: Station is on WOC below the confluence with First Creek and Northwest Tributary where Melton Valley Drive meets Lagoon Road. The control device is a compound stainless steel sharp-crested weir consisting of a low-flow trapezoidal section, a trapezoidal transition section, and a rectangular high-flow section.

Monitoring status: USGS instrumentation includes a bubbler gage equipped with a digital punch, stage-height recorder that transmits stage data via a satellite telemetry system to the USGS data base in Nashville, TN. Stage or converted discharge data are available in near real-time for immediate access, and are also processed to produce on-line computer summaries of data. This site also has a raingage that is part of the data collection platform (DCP) system in use. In addition, ESP operates a flow totalizer at this station.

21. Melton Branch Tributary (East Seven, GS16, USGS #03537050)

Physical description: Station is on the east tributary (East Seven Creek) to MB adjacent to the proposed SWSA 7. The control device is a prefabricated fiberglass H-flume.

Monitoring status: USGS instrumentation includes a Stevens model 7001 float-type gage housed over a stilling well and equipped with a digital punch, stage-height recorder that collects raw stage data at 15-min intervals for conversion to hourly average discharge values.

22. Upper Melton Branch (GS2, USGS #03537100)

Physical description: Station is in the upper reaches of MB near the proposed SWSA 7, 1.6 kilometers (1 mile) southeast of ORNL, just upstream from the High Flux Isotope Reactor (HFIR) complex. The control device is a "natural" concrete overflow sill with a broad, flat, triangular notch.

Monitoring status: USGS instrumentation includes a Stevens model 7001 float-type gage housed over a stilling well and equipped with a digital punch, stage-height recorder that collects raw stage data at 15-min intervals for conversion to hourly average discharge values.

23. Melton Branch Tributary (Center Seven, GS17, USGS #03537200)

Physical description: Station is at the center of three tributaries (Center Seven Creek) to MB, adjacent to the proposed SWSA 7. The low-flow control device is a stainless steel, sharp-crested, 90° V-notch weir and the high-flow control device is a 0.76 m (2.5 ft), fiberglass H-flume.

Monitoring status: USGS instrumentation includes a Stevens model 7001 float-type gage housed over a stilling well and equipped with a digital punch stage-height recorder for measuring stage over the H-flume at 15-min intervals for conversion to hourly average discharge values. ESD installed the V-notch weir for better resolution on low flows. It, too, is equipped with an electronic data logger and a submerged pressure transducer for stage-height measurements.

24. Melton Branch Tributary (West Seven, GS18, USGS #03537300)

Physical description: Station is on the west tributary (West Seven Creek) to MB adjacent to the proposed SWSA 7. The control device is a combination stainless steel rectangular/90° V-notch weir.

Monitoring status: USGS instrumentation included a Stevens model 7001 float-type gage housed over a stilling well and equipped with a digital punch stage-height recorder. This station was discontinued by the USGS in September 1989.

Rating tables for most of these monitoring stations are available in Appendix B. In most cases, the tables can be used in the field without applying an offset. That is, the stage height can be read by visual inspection of the staff gage and applied directly to the rating table to determine the corresponding discharge. In addition, most of the tables are in English units (head or stage in feet and discharge in cubic feet per second), but for those that are not, units are clearly stated. For example, at the MS3 monitoring station above the confluence with MB, for a staff gage reading of 0.95 ft, the corresponding discharge is 5.40 cfs. **The rating tables are provided as a reference, and the reader is cautioned to apply these ratings carefully. Many circumstances can render these ratings temporarily or permanently invalid.**

Tables 8 and 9 allow comparison of flows at selected gaging stations, monthly discharge and runoff summaries for the nine ESD sites (for which data are available from the ESD Watershed Hydrology Group) and eight USGS sites (for which data are available in the RAP DIMS consolidated data base). The total monthly volume of runoff (natural and imported) from each station was divided by its drainage area to express monthly runoff volume in inches of water. Historically, loss of water to the atmosphere is approximately 55% of the total annual precipitation in the Oak Ridge area. The remaining 45%, on the average, occurs as runoff. At a number of stations (GS1, GS3, and GS5) in the main plant area or downstream from plant effluents, runoff volumes are greater than precipitation totals for several months

**Table 8. Monthly flow and runoff statistics for ESD stations located in the vicinity of WOC watershed
Flow rate units=cfs**

			SITE ID					
YEAR	MONTH	STATISTIC	WOCHW	WOC	MBR	WOD	E.SEEP	W.SEEP
1989	OCTOBER	MEAN	1.85	14.02	1.44	16.48	0.06	0.38
		MINIMUM	0.46	5.79	0.52	6.45	0.02	0.07
		MAXIMUM	19.70	89.95	7.82	174.73	0.60	4.71
		RUNOFF (IN.)	2.65	4.48	1.10	3.09	2.16	1.75
	NOVEMBER	MEAN	2.10	15.36	3.14	19.90	0.09	0.92
		MINIMUM	0.35	6.01	0.50	6.58	0.01	0.07
		MAXIMUM	12.13	54.12	9.43	96.38	0.35	4.26
		RUNOFF (IN.)	2.91	4.75	2.32	1.80	3.14	4.09
	DECEMBER	MEAN	1.03	9.90	1.38	12.27	0.07	0.52
		MINIMUM	0.54	6.56	0.58	7.53	0.03	0.18
		MAXIMUM	6.35	57.07	3.16	81.95	0.57	5.55
		RUNOFF (IN.)	1.48	3.16	1.05	2.30	2.52	2.39
1990	JANUARY	MEAN	2.90	17.66	4.81	26.10	0.12	1.11
		MINIMUM	0.99	10.09	1.36	10.71	0.03	0.23
		MAXIMUM	6.99	30.62	13.23	71.51	0.46	4.59
		RUNOFF (IN.)	4.16	5.64	3.67	1.14	4.32	5.10
	FEBUARY	MEAN	5.19	28.20	6.07	40.43	0.18	1.81
		MINIMUM	1.63	10.45	1.81	13.33	0.05	0.47
		MAXIMUM	18.52	90.41	44.08	161.38	0.80	7.81
		RUNOFF (IN.)	6.72	8.13	4.18	6.84	5.86	7.51
	MARCH	MEAN	2.70	17.13	4.97	22.88	0.10	0.94
		MINIMUM	1.00	8.43	1.26	10.26	0.04	0.26
		MAXIMUM	19.34	96.97	40.92	173.94	0.71	7.35
		RUNOFF (IN.)	3.87	5.47	3.79	4.29	3.60	4.32

Table 8 (continued)

			SITE ID					
YEAR	MONTH	STATISTIC	WOCHW	WOC	MBR	WOD	E.SEEP	W.SEEP
	APRIL	MEAN	0.85	8.58	1.74	10.28	0.04	0.28
		MINIMUM	0.73	7.27	1.00	8.26	0.02	0.17
		MAXIMUM	0.95	12.61	4.60	16.43	0.07	0.46
		RUNOFF (IN.)	1.18	2.65	1.29	1.87	1.40	1.25
	MAY	MEAN	1.80	16.46	5.06	22.66	0.15	0.86
		MINIMUM	0.64	6.75	1.09	7.97	0.02	0.12
		MAXIMUM	6.87	62.68	31.16	91.42	0.68	4.89
		RUNOFF (IN.)	2.58	5.26	3.86	4.25	5.41	3.95
	JUNE	MEAN	1.00	7.03	1.15	8.01	0.02	0.13
		MINIMUM	0.55	5.48	0.65	6.05	0.00	0.02
		MAXIMUM	2.05	14.64	2.56	18.29	0.10	0.77
		RUNOFF (IN.)	1.39	2.17	0.85	1.45	0.70	0.58
	JULY	MEAN	0.33	10.32	2.08	11.88	0.04	0.29
		MINIMUM	0.29	5.84	0.68	5.38	0.00	0.02
		MAXIMUM	0.39	37.10	14.69	60.71	0.30	2.52
		RUNOFF (IN.)	0.47	3.30	1.59	2.23	1.44	0.13
	AUGUST	MEAN	1.089	10.52	1.81	11.07	0.03	0.16
		MINIMUM	0.27	5.95	0.81	5.24	0.00	0.02
		MAXIMUM	2.750	31.94	6.16	43.75	0.10	0.81
		RUNOFF (IN.)	1.56	3.36	1.38	2.08	1.08	0.73

Table 8 (continued)

			SITE ID					
YEAR	MONTH	STATISTIC	WOCHW	WOC	MBR	WOD	E.SEEP	W.SEEP
	SEPTEMBER	MEAN	0.424	6.03	0.93	6.39	0.01	0.04
		MINIMUM	0.262	4.97	0.64	5.62	0.00	0.02
		MAXIMUM	0.611	10.71	2.12	12.61	0.03	0.29
		RUNOFF (IN.)	0.61	1.86	0.69	1.16	0.35	0.18

WOCHW=Whiteoak Creek Headwaters
WOC=Whiteoak Creek
MBR=Melton Branch
WOD=Whiteoak Dam
E.SEEP=East Seep
W.SEEP=West Seep

Table 9. Monthly flow and runoff statistics for USGS stations located in the vicinity of WOC watershed
Flow rate units=cfs

			SITE ID							
YEAR	MONTH	STATISTIC	GS1	GS2	GS3	GS4	GS5	GS6	GS16	GS17
1989	OCTOBER	MEAN	1.01	0.71	11.20	1.33	6.46	1.87	0.31	0.11
		MINIMUM	0.32	0.06	5.50	0.50	2.90	0.09	0.04	0.03
		MAXIMUM	8.20	11.00	72.00	14.00	49.00	28.00	5.20	1.60
		RUNOFF (IN.)	3.53	1.58	3.94	2.29	3.55	1.64	1.51	1.82
	NOVEMBER	MEAN	1.44	1.17	14.80	1.78	8.65	2.63	0.61	0.18
		MINIMUM	0.24	0.03	5.70	0.47	2.90	0.10	0.05	0.03
		MAXIMUM	4.90	6.40	49.00	8.80	36.00	16.00	4.00	0.95
		RUNOFF (IN.)	4.87	2.51	5.04	2.96	4.60	2.24	2.85	2.94
	DECEMBER	MEAN	0.74	0.64	9.06	1.00	4.74	1.12	0.33	0.11
		MINIMUM	0.38	0.16	6.10	0.53	2.80	0.16	0.05	0.03
		MAXIMUM	4.90	8.30	47.00	9.80	30.00	14.00	5.10	1.40
		RUNOFF (IN.)	2.50	1.42	3.18	1.72	2.60	0.98	1.60	1.82
1990	JANUARY	MEAN	2.01	1.94	19.20	2.47	10.90	3.67	0.94	0.28
		MINIMUM	0.72	0.44	8.90	8.60	4.40	0.73	0.15	0.06
		MAXIMUM	4.90	8.40	47.00	0.66	28.00	13.00	4.50	1.30
		RUNOFF (IN.)	7.02	4.29	6.75	4.25	5.98	3.23	4.53	4.53
	FEBRUARY	MEAN	2.86	3.15	26.00	3.96	16.70	6.69	1.38	0.44
		MINIMUM	0.98	0.59	10.00	0.90	5.60	1.30	0.20	0.09
		MAXIMUM	8.30	15.00	73.00	16.00	58.00	25.00	7.60	2.30
		RUNOFF (IN.)	9.02	6.31	8.25	6.15	8.28	5.32	6.01	6.56
	MARCH	MEAN	1.63	1.71	16.00	2.11	9.41	3.21	0.74	0.25
		MINIMUM	0.72	0.38	8.00	0.75	4.30	0.69	0.14	0.08
		MAXIMUM	9.10	14.00	74.00	16.00	51.00	28.00	6.50	2.10
		RUNOFF (IN.)	5.70	3.79	5.62	3.63	5.17	2.83	3.57	4.14

Table 9 (continued)

			SITE ID							
YEAR	MONTH	STATISTIC	GS1	GS2	GS3	GS4	GS5	GS6	GS16	GS17
	APRIL	MEAN	0.75	0.59	8.33	0.76	4.38	0.54	0.25	0.10
		MINIMUM	0.59	0.29	7.00	0.61	3.40	0.28	0.10	0.06
		MAXIMUM	1.20	1.60	13.00	1.10	7.90	1.10	0.67	0.28
		RUNOFF (IN.)	2.54	1.28	2.83	1.27	2.33	0.46	1.14	1.58
	MAY	MEAN	1.55	1.52	15.50	1.95	8.24	2.27	0.69	0.24
		MINIMUM	0.77	0.14	6.50	0.48	3.10	0.12	0.04	0.05
		MAXIMUM	6.40	11.00	50.00	12.00	28.00	12.00	5.00	1.90
		RUNOFF (IN.)	5.41	2.92	5.45	3.36	4.52	2.00	3.30	3.99
	JUNE	MEAN	0.40	0.07	7.15	0.55	3.71	0.38	0.03	0.03
		MINIMUM	0.20	0.00	14.00	0.44	2.70	0.04	0.00	0.01
		MAXIMUM	1.00	0.32	5.70	1.10	9.40	3.30	0.19	0.09
		RUNOFF (IN.)	1.35	0.15	2.43	0.92	1.97	0.32	0.16	0.43
	JULY	MEAN	0.67	0.32	9.86	0.92	5.19	0.84	0.17	0.07
		MINIMUM	0.24	0.00	5.60	0.42	2.50	0.04	0.00	0.01
		MAXIMUM	2.80	3.60	31.00	3.60	20.00	6.90	2.00	0.09
		RUNOFF (IN.)	2.34	0.70	3.47	1.58	2.85	0.74	0.82	0.43
	AUGUST	MEAN	0.56	0.17	10.60	0.77	6.15	1.77	0.10	0.05
		MINIMUM	0.23	0.00	6.20	0.47	2.50	0.05	0.00	0.01
		MAXIMUM	1.70	1.40	34.00	1.80	26.00	18.00	1.10	0.30
		RUNOFF (IN.)	1.96	0.37	3.73	1.33	3.38	1.56	0.50	0.73

Table 9 (continued)

			SITE ID							
YEAR	MONTH	STATISTIC	GS1	GS2	GS3	GS4	GS5	GS6	GS16	GS17
	SEPTEMBER	MEAN	0.22	0.01	5.74	0.46	2.72	0.10	0.01	0.01
		MINIMUM	0.14	0.00	4.70	0.41	2.10	0.04	0.00	0.01
		MAXIMUM	0.44	0.17	8.60	0.88	5.20	0.98	0.08	0.07
		RUNOFF (IN.)	0.74	0.02	1.95	0.77	1.45	0.09	0.03	0.20

GS1=First Creek
GS2=Melton Branch near Melton Hill
GS3=WOC below Melton Valley Drive
GS4=Northwest Trib near Oak Ridge
GS5=WOC near Wheat, TN
GS6=WOC near Melton Hill
GS16=Melton Branch Tributary (East Seven) near Oak Ridge
GS17=Melton Branch Tributary (Center Seven) near Oak Ridge

of the Water Year (see Table 9). In addition, annual runoff volume approaches annual precipitation totals at the same stations: approximately 83% at GS1, 92% at GS3, and 83% at GS5. This highlights the magnitude and influence of imported water to monitoring stations in the WOC watershed. For comparison, two gaging stations upstream of ORNL effluents, GS2 and the WOC Headwaters (WOCHW) station, had runoff volumes of approximately 46% and 48%, respectively. Drainage areas for each station in the flow system are listed in Table 10. Daily flow data for these sites are listed in tables in Appendix C.

Flow in WOC in the main ORNL plant area is increased by the disposal of water imported for plant processes, potable supplies, and sanitary use. The flow is complex because of the effects of storm drainage, leakage into and out of an extensive system of underground pipes, and the increased permeability of disturbed subsurface materials along pipe lines and within construction sites. However, the discharge data from the six USGS stations in the vicinity of the main plant permit the isolation of flow from contributing areas where the majority of plant effluents and imported water enter the surface-water system. Figure 19 shows hydrographs of monthly mean discharge at station GS3 on WOC downstream from the main plant area, GS4 on the Northwest Tributary, GS1 on First Creek, GS5 on WOC below its junction with Fifth Creek, and the difference between flow at GS3 and the sum of the three upstream stations. This difference, consistently above 2 cfs, includes runoff from the contributing area between the three upstream stations and GS3 (approximately 0.18 mi^2), as well as, and most significantly, the three major effluent discharges regulated under the ORNL NPDES permit (the Sewage Treatment Plant [Q_{avg} = 0.36 cfs], the Coal Yard Runoff Treatment Facility [Q_{avg} = 0.045 cfs], and the Nonradiological Wastewater Treatment Facility [Q_{avg} = 0.69 cfs]). These values are taken from the NPDES permit renewal application.

Figure 20 shows monthly mean discharge at WOC station GS5 compared to discharge at station GS6 which is outside the east gate of the main plant and upstream of most plant activities and effluents. The difference in flow between these stations includes the runoff from the contributing drainage area between the stations (approximately 0.8 mi^2). This area drains Fifth Creek as well as a number of minor effluent discharges from ORNL facilities, including Category I and II outfalls, cooling water discharges, and miscellaneous source discharges.

Figure 21 shows monthly mean discharge in WOC at GS3 downstream from Haw Ridge, at monitoring station 3 (MS3) on WOC upstream from the confluence with MB, and the difference between monthly discharge at the two stations. Unpublished stream surveys done by the USGS in the late 1980s indicated that the average difference between GS3 and MS3 was approximately 4.5% (D. D. Huff, Oak Ridge National Laboratory, personal communication to D. M. Borders, The University of Tennessee, Knoxville, August 1991; G. K. Moore, The University of Tennessee, Knoxville, personal communication to D. M. Borders, The University of Tennessee, Knoxville, August 1991), indicating that this section of WOC is a gaining reach. The comparison of discharge at these stations showed negative differences in flow for more than half the year (8 months) for the last data reporting period (May 1987–April 1988) despite the 0.34 mi^2 of contributing drainage area between the stations. This had cast strong doubt on the accuracy of the flow measurements. In June 1988, the monitoring station at GS3 was upgraded with an improved hydraulic control device. In addition, the ESD Watershed Hydrology Group began collecting and processing discharge

Table 10. Drainage areas of discharge monitoring stations located in the vicinity of the Whiteoak Creek Watershed

MONITORING STATION	COMMON STATION NAME(S)	DRAINAGE AREA (mi^2)
GS1	First Creek	0.33
GS2	Upper Melton Branch (UMB)	0.52
GS3	7500 Bridge	3.28
GS4	Northwest Tributary (NWT)	0.67
GS5	Parshall Flume, MS2	2.10
GS6	Upper WOC	1.31
GS16	East Seven Creek (E7C)	0.24
GS17	Center Seven Creek (C7C)	0.07
MS3	WOC, X14	3.61
MS4	MBR, X13	1.51
MS5	WOD, X15	6.15
WOCHW	WOC Headwaters	0.80
East Seep	East Seep Tributary	0.03
West Seep	West Seep Tributary	0.25
MS1	SWSA 4 Tributary	0.04
Ish Creek	Ish Creek	0.95
Raccoon Creek	Raccoon Creek	0.33

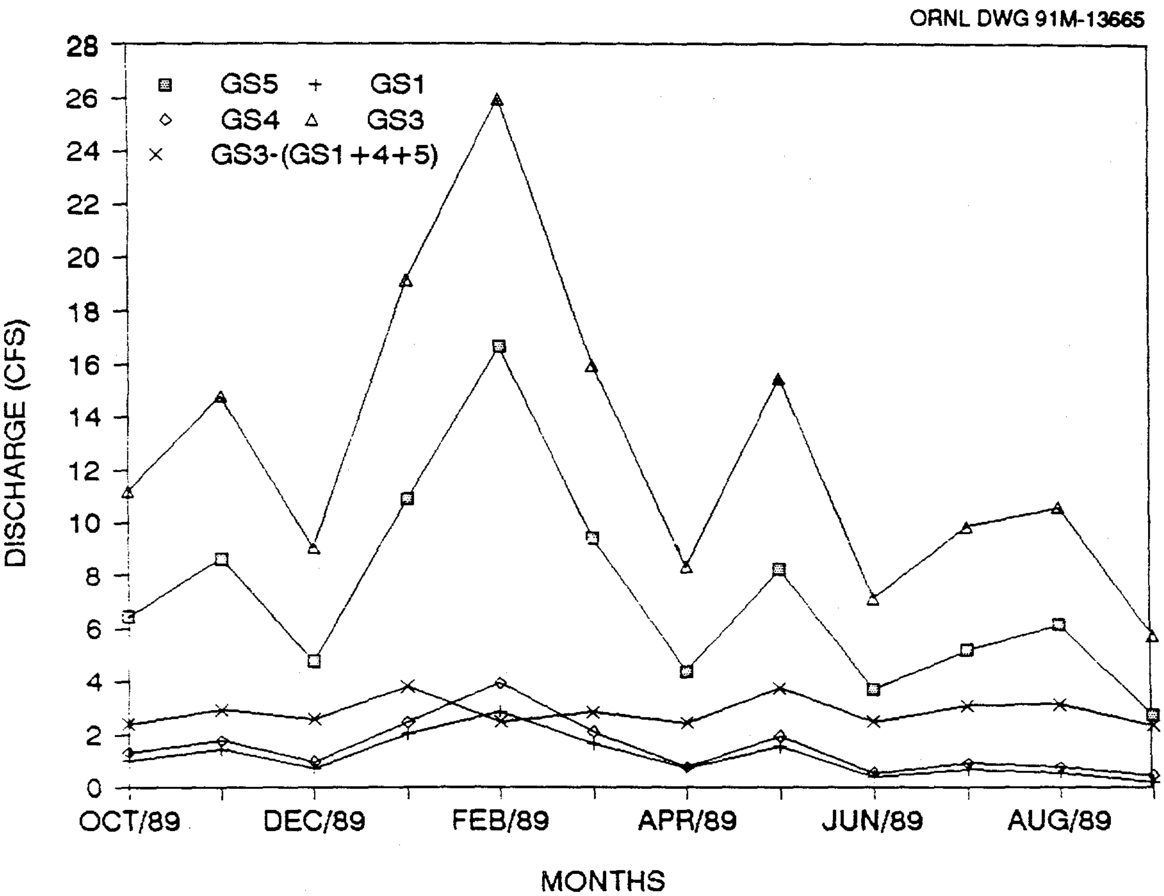

Fig. 19. Comparison of monthly mean discharge at USGS monitoring stations GS1, GS3, and GS4.

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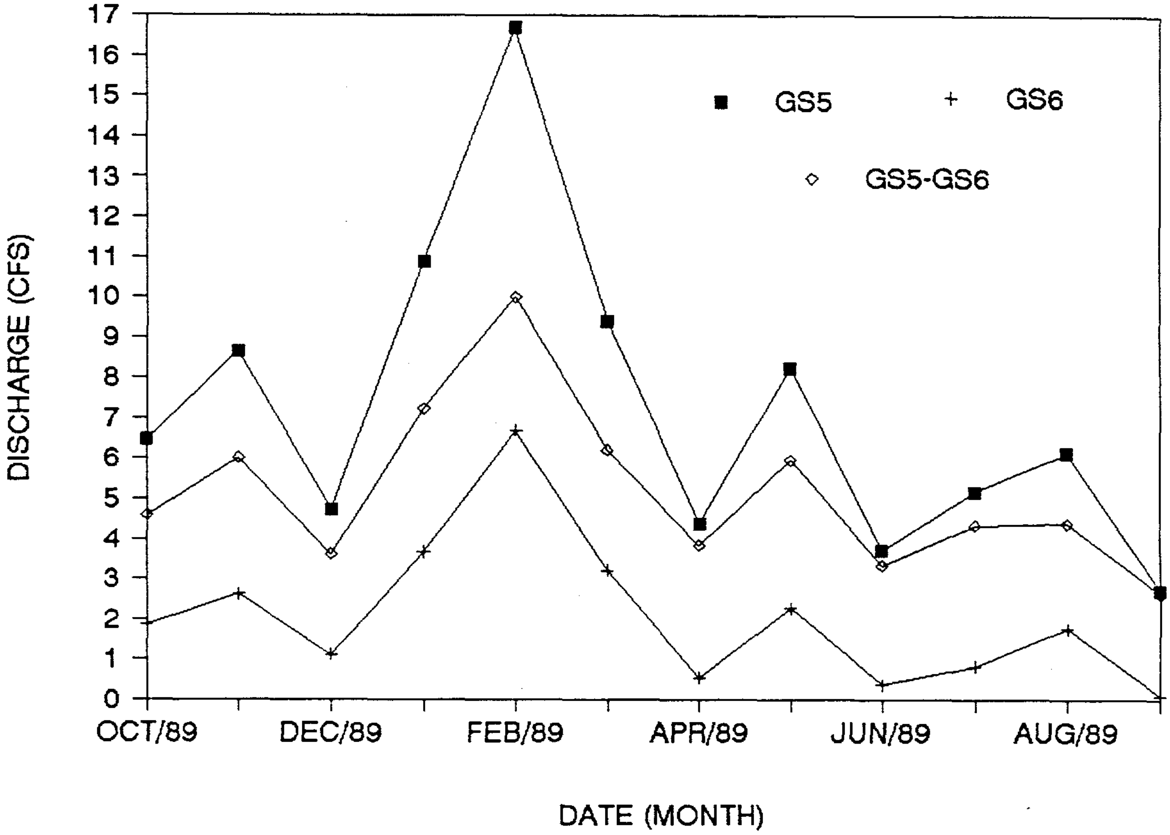

Fig. 20. Comparison of monthly mean discharge at USGS monitoring stations GS5 and GS6.

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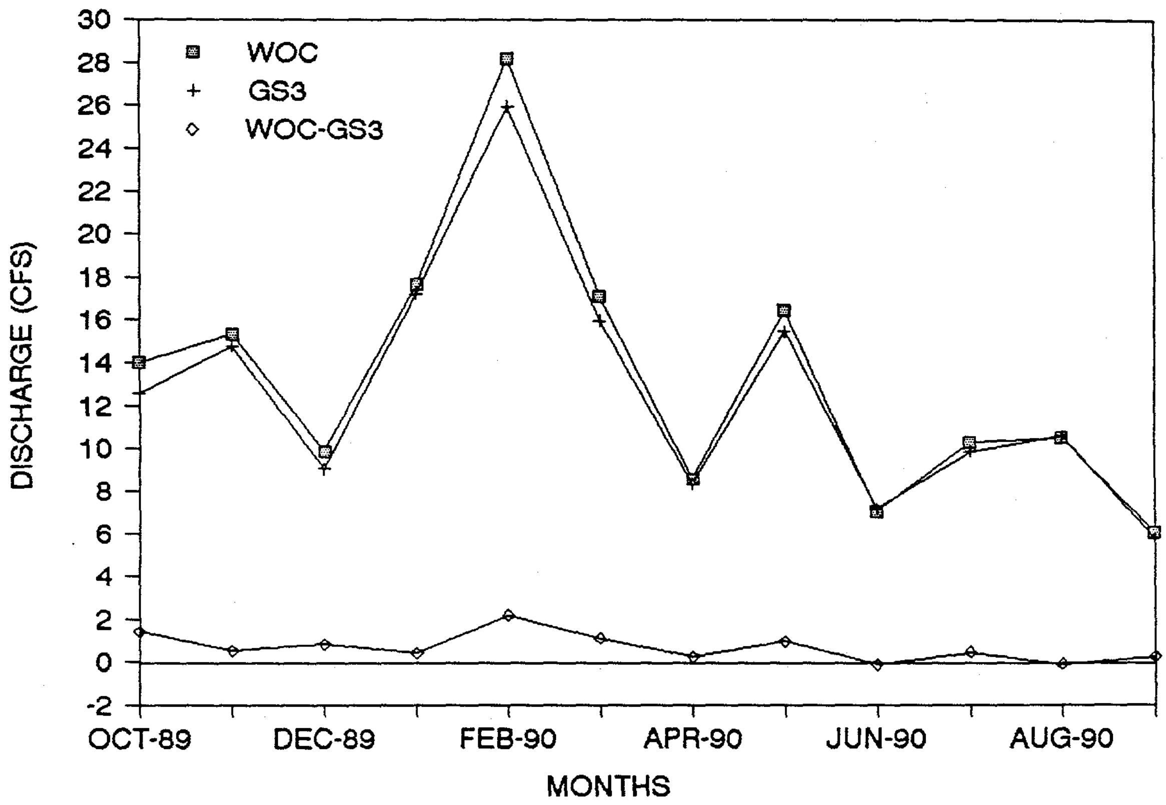

Fig. 21. Comparison of monthly mean discharge at USGS monitoring station GS3 and ESD monitoring station MS3.

data at MS3 and other "major" monitoring stations on the watershed shortly after the end of the previous reporting period. Differences in monthly discharge for Water Year 1990 were positive every month except June (-1.6%) and August (-0.7%) of 1990, typically two of the driest months of the year. The average difference in monthly discharge values for the year was 4.9%. This suggests that the accuracy of discharge measurments at these two sites has improved significantly.

The negative differences in discharge between station MS3 and the upstream station GS3 are partly due to conditions mentioned above. Silt can obstruct of the stilling well intake line, delaying and reducing the rise of water levels inside the stilling well (where stage recording instruments are located) at MS3. This reduces rates and total volumes recorded for storm events. These problems make it clear that structures and equipment must be regularly inspected and maintained to ensure quality data.

Flow in Melton Branch was augmented by effluent discharges of about 0.25 cfs from the High Flux Isotope Reactor (HFIR) and about 0.08 cfs from the Transuranium Processing Facility (TRU) until November 1986 when the HFIR was shut down and discharges were substantially reduced. The reactor began operating again in January 1990 and reached full power in May 1990. However, in February 1990, the NRWTF went online to treat dilute ORNL process waste streams. This facility now receives the waste effluents from both the TRU (X08) and HFIR (X09), facilities which were previously routed to temporary holding ponds 7908 and 7909, and 7905, respectively, before being released to MB. Currently, MB receives blowdown from the HFIR, an unidentified process water discharge coming from the headwaters region of the HRE tributary, and rainfall runoff.

The source of the process water discharge to the HRE tributary may be cooling water from the Molten Salt Reactor Experiment. On June 14-16, 1988, continuous discharge measurements were collected at the HRT/HRE monitoring station (#14 above) for a dye tracer test (D. S. Wickliff, Oak Ridge National Laboratory, personal communication to D. M. Borders, University of Tennessee, August 1991). Discharge measurements for this period fluctuated on a daily cycle from approximately 180 to 300 L/min (approximately 0.11 to 0.18 cfs), with the higher flows generally occurring during daylight hours. For the same period, the USGS monitoring station on MB (#22 above), upstream from the confluence with the HRE tributary, recorded no flow, and in fact recorded no flow for the entire month of June. In addition, according to data collected from the ESP data aquisition system (DAS), discharge at the monitoring station on MB (MS4, #3 above), immediately upstream from the confluence with WOC, ranged from approximately 0.07 to 0.17 cfs over the three-day period. Discharge at MS4 fluctuated, but with a less distinct trend. This suggests that, during the time period examined, since there is no baseflow production in the headwaters of MB, all of the discharge at MS4 on MB could possibly be attributed to the HRE tributary (minus losses) with the majority being process water. Figure 22 shows monthly mean discharge at MS3 on WOC, monitoring station 4 (MS4) on MB above the confluence with WOC, monitoring station 5 (MS5) at WOD, and the differences between the sum of flows at MS3 and MS4 and the flow at WOD (MS5). The occurrence of negative flows, despite an appreciable contributing drainage area (1.04 mi^2), highlights the need for field rating and verification of the high-flow, stage-discharge relationships at each of the three gaging stations (see Section 1.1.1). However, all the negative differences occurred in these months (April, June-

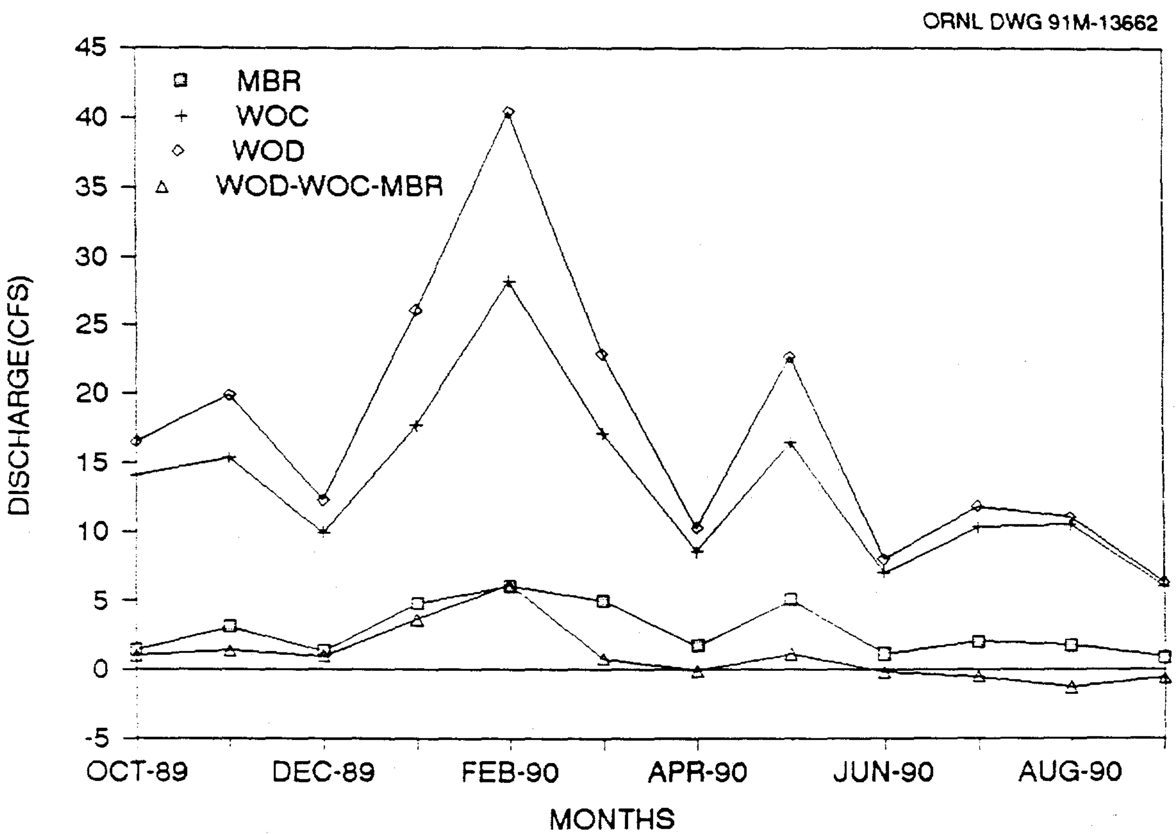

Fig. 22. Comparison of monthly mean discharge at monitoring stations MS3, MS4, and MS5.

September, 1990) with below-average precipitation, or in the summer and early autumn when evapotranspiration rates are higher and soil moisture deficits tend to be high, resulting in less runoff. Local inflows from ungaged areas around the lake are also negligible at these times. In addition, sections of lower WOC above the headwaters of WOL may be losing reaches, and WOL presents a significant surface area for losses due to evaporation during hot, dry periods. Therefore, a significant portion of the negative differences may be accountable. Nevertheless, the causes of these negative differences should be verified or corrected.

3.2.2 Surface Water Quality

As part of the NPDES program, ESP monitors surface water quality for both radiological and chemical constituents at a number of sites in the WOC flow system. Additional water quality data have been collected at selected sites as part of the BMAP activities and other RAP studies. These in-stream sites are shown in Fig. 23.

Summaries of chemical and radiological data for in-stream monitoring sites appear in the previous ESP environmental data reports (MMES 1989d, 1990a, b, c) and also in the annual environmental reports for the ORR [Environmental Safety and Health 1990 - ES/ESH-13 and ES/ESH-18 (unpublished)]. Additional analytical results for chemical and physical parameters at the ESP sites and at a number of upstream reference sites are included in the BMAP annual report for 1990 (Loar et al. 1991). Table 11 shows selected physical and chemical parameters routinely monitored at the primary NPDES/ESP in-stream sites (among others) for the current reporting period. Table 12 shows the chemical and physical parameters collected by the BMAP for discrete water quality sampling at 10 sites in WOC and its tributaries during the same period.

Monthly discharge of selected radionuclides at the primary ESP in-stream sites is calculated from flow and concentration values and presented in the quarterly environmental data reports. Figures 24–27 show the discharge of ^{137}Cs, total radiological Sr, ^{60}Co, and ^{3}H at WOC (X14), MB (X13), and WOD (X15) for Water Year 1990. The data in Fig. 27 show inconsistency during some months. The discharge of tritium (^{3}H) at the basin outlet (X15) is shown as being less than that of an upstream tributary (MB) in May 1990. In addition, monthly totals of ^{3}H and total strontium at WOD are less than the sum of WOC (X14) and MB (X13), again most notably for May 1990. These results suggest a possible problem with the procedure used for compositing flow-proportional samples from high, medium, and low ranges of flow rates. However, results also suggest an improvement in accuracy since the reporting period of May 1987 through April 1988.

Submerged flow conditions have been documented at the MB monitoring station during high-flow events. Channel constriction downstream of the flow structure causes a backwater effect resulting in higher water levels during these events. Since the instruments were designed and calibrated for freeflow (unobstructed) conditions, flow rates are actually lower than recorded water surface levels would indicate when submergence occurs. Therefore, since the volume of water is overestimated, the total mass of constituents (such as tritium) is also overestimated. The storm of May 1, 1990 produced the highest flow rates of the current reporting period, thereby introducing the greatest error in measurement totals for the month of May. Steps are now being taken to resolve this matter.

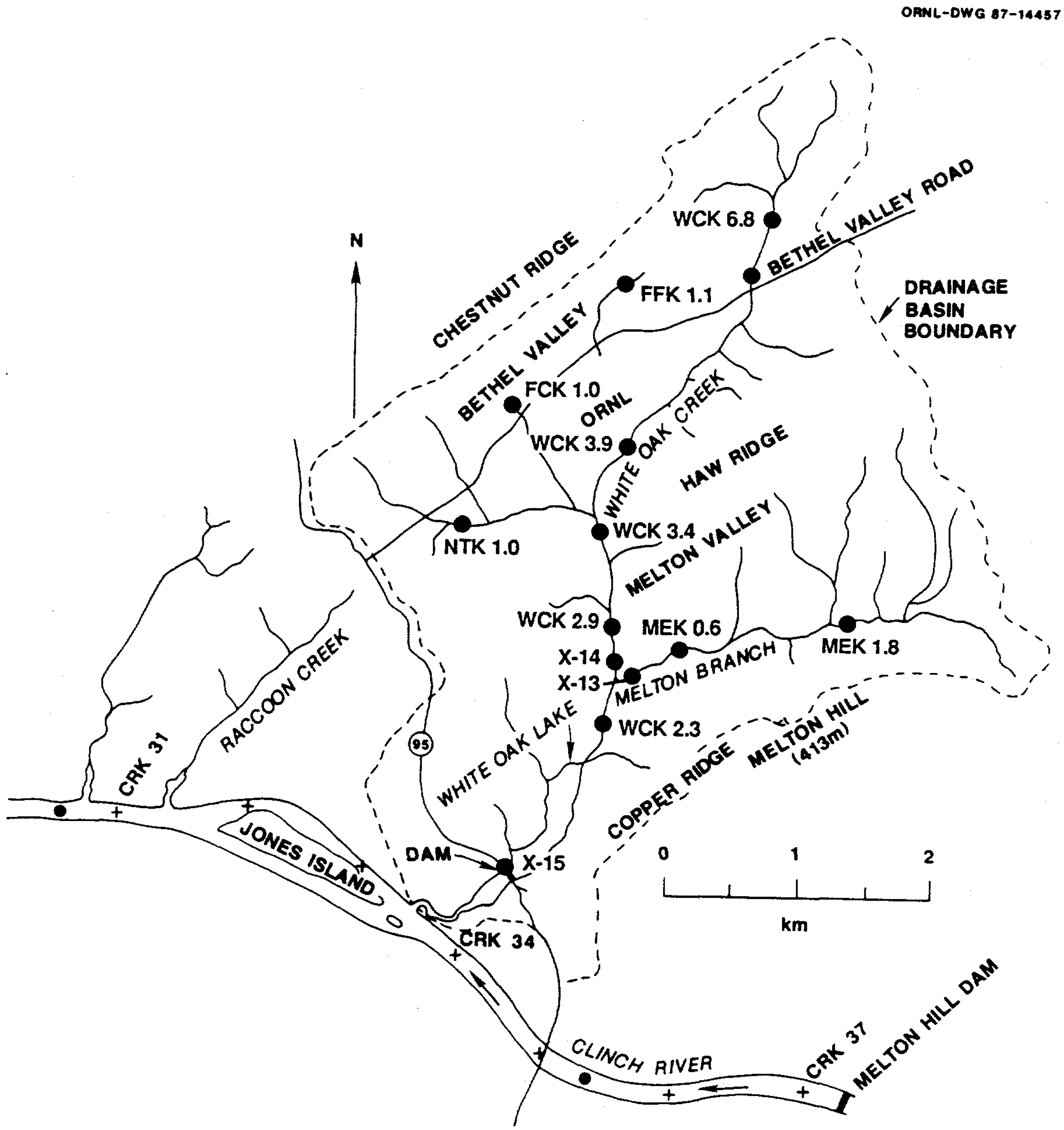

Fig. 23. Surface water quality monitoring or sampling sites in WOC and its tributaries.

Table 11. Availability of Whiteoak Creek Watershed environmental monitoring data from Environmental Surveillance and Protection Section, Information Integration and Analysis Group for Water Year 1990

Where[a]	Flow	General indicators	Inorganics	Organics	Radionuclides	Contact
[B]WOC headwaters (see Figure 3.4 from the 1990 annual report, figure attached) --surface water	totalizer --weekly	pH, oil & grease, total dissolved solids, specific conductance, dissolved oxygen, total organic carbon, temperature, turbidity, total suspended solids --monthly grab sample	ICP metals and selected AA metals, anions --monthly grab sample		gross alpha, gross beta, gamma scan --on monthly flow-proportional composite isotopic alpha (Am-241, Cm-244, Pu-238, Pu-239, Th-228, Th-230, Th-233, U-234, U-235 and U-238) ---when gross alpha exceeds 1 Bq/L total radioactive strontium --when gross beta exceeds 30 Bq/L	D. A. Wolf -- for rads A. E. Osborne-Lee --otherwise
[AB]various locations in WOC watershed (see Figure 3.14 from the 1990 annual report, figure attached) --surface water --sediments				total PCBs --quarterly surface water grab sample total PCBs, total organic carbon --semi-annual sediment grab sample		A. E. Osborne-Lee
[AB]various locations in WOC watershed (see Figures 3.11 and 3.12 from the 1990 annual report, figure attached) --surface water --sediments			mercury --semi-annual surface water grab sample --semi-annual sediment grab sample			A. E. Osborne-Lee

Table 11 (continued)

[A]7500 bridge, Melton Branch 2 and Northwest tributary (see Figure 3.4 from the 1990 annual report, figure attached) --surface water	totalizer --weekly				for 7500 bridge, Melton Branch 2: H-3, gamma scan, and total radioactive strontium for Northwest tributary: gamma scan, total radioactive strontium --analysis of a monthly composite of weekly flow-proportional samples	D. A. Wolf
[A]First Creek, Fifth Creek and Raccoon Creek (see Figure 3.4 from the 1990 annual report, figure attached)	creek level --weekly				gamma scan, total radioactive strontium --analysis of a monthly composite of weekly grab samples	D. A. Wolf
[A]White Oak Dam (X15) (see Figure 3.4 or 310 from the 1990 annual report, figure attached) --surface water	totalizer --daily	See Table 2.2.53 in volume 2 of the 1989 and Table 3.41 in volume 2 of the 1990 annual reports for sampling and analysis frequencies.			gamma scan, gross alpha, gross beta --analysis of weekly flow-proportional samples H-3, total radioactive strontium --analysis of a monthly composite of weekly flow-proportional samples isotopic alpha (Am-241, Cm-244, Pu-238, Pu-239, Th-228, Th-230, Th-233, U-234, U-235 and U-238) ---when gross alpha exceeds 1 Bq/L	D. A. Wolf --for rads P. Y. Goldberg --otherwise
WAG 1 (see Figure 4.6 from the 1990 annual report, figure attached) --groundwater	Not Applicable	pH, specific conductance, temperature, alkalinity, total organic halides, total organic carbon, total suspended solids, total dissolved solids --semiannually	ICP metals, selected AA metals, TKN, anions, cyanide	volatiles, BNAEs, PCBs and pesticides/ herbicides	gamma scan, H-3, gross alpha, gross beta isotopic alpha (Am-241, Cm-244, Pu-238, Pu-239, Th-228, Th-230, Th-233, U-234, U-235 and U-238) --when gross alpha exceeds 0.5 Bq/L total radioactive strontium --when gross beta exceeds 0.9 Bq/L	R. S. Loffman

Table 11 (continued)

[E]Sewage Treatment Plant (X01) (see Figure 3.10 from the 1990 annual report, figure attached) --surface water	totalizer --daily	See Table 2.2.40 in volume 2 of the 1989 and Table 3.38 in the 1990 annual reports for sampling and analysis frequencies.	gamma scan, gross beta, total radioactive strontium --analysis of monthly composite of weekly flow proportional samples	D. A. Wolf --for rads P. Y. Goldberg --otherwise
[E]Coalyard Runoff Treatment Facility (X02), (see Figure 3.10 from the 1990 annual report, figure attached) --surface water	totalizer --daily	See Table 2.2.41 in volume 2 of the 1989 and Table 3.39 in the 1990 annual reports for sampling and analysis frequencies.		P. Y. Goldberg
[E]Sewage Treatment Plant (X01), Coalyard Runoff Treatment Facility (X02), Melton Branch (X13), Nonradiological Wastewater Treatment Facility (X12) (came on line 1 April 1990) and White Oak Creek (X14) (see Figure 3.10 from the 1990 annual report, figure attached) --surface water	Toxicity tests using fathead minnows and *Ceriodaphnia* See the description pertaining to Tables 2.2.30 and 2.2.31 in volume 1 of the 1989 and Tables 3.31 and 3.32 in the 1990 annual reports.			A. J. Stewart
[E]Nonradiological Wastewater Treatment Facility (X12) (came on line 1 April 1990) (see Figure 3.10 from the 1990 annual report, figure attached) --surface water	totalizer --daily	See Table 3.44 for sampling and analysis frequencies see volume 2 of the 1990 annual report.	H-3, gamma scan, gross alpha, gross beta, total radioactive strontium --analysis of monthly composite of weekly flow proportional samples	D. A. Wolf --for rads P. Y. Goldberg --otherwise
[E]Various other effluent points into WOC or its tributaries (including storm drains, parking lot drains, storage area drains, once-through condensate, process and lab drains, steam plant and cooling tower blowdown)	See Tables 2.2.40-2.2.61 in the 1989 and Tables 3.48-3.54 in the 1990 annual reports for sampling and analysis frequencies.		gross beta on category 2 outfalls --quarterly analysis of grab sample	P. Y. Goldberg
[A]Melton Branch 1 (X13) and WOC (X14) (see Figure 3.4 or 310 from the 1990 annual report, figure attached) --surface water	totalizer --daily	See Tables 2.2.51 and 2.2.52 in the 1989 and Tables 3.45-3.46 in the 1990 annual reports for the sampling and analysis frequencies.	H-3, gamma scan, and total radioactive strontium --analysis of a monthly composite of weekly flow-proportional samples	D. A. Wolf --for rads P. Y. Goldberg --otherwise

Table 11 (continued)

WAG 5 (see Figure 4.6 from the 1990 annual report, figure attached) --groundwater	Not Applicable	pH, specific conductance, temperature, alkalinity, total organic halides, total organic carbon, total suspended solids, total dissolved solids --semiannually	ICP metals, selected AA metals, uranium fluorometric, anions		gamma scan, H-3, total radioactive strontium, gross alpha, gross beta	D. A. Wolf
WAG 7 (see Figure 4.6 from the 1990 annual report, figure attached) --groundwater	Not Applicable	pH, specific conductance, temperature, alkalinity, total organic halides, total organic carbon, total suspended solids, total dissolved solids --semiannually	ICP metals, selected AA metals, uranium fluorometric, anions		gamma scan, H-3, total radioactive strontium, gross alpha, gross beta, Tc-99	D. A. Wolf
SWSA 6 (see Figure 4.6 from the 1990 annual report, figure attached) --groundwater	Not Applicable	pH, specific conductance, temperature, alkalinity --semiannually		volatiles --semiannually	gamma scan, H-3, total radioactive strontium and gross alpha --semiannually	D. A. Wolf

[a]Station(s) or groups of stations are preceded by a character denoting the station type: B=Background reference station, E=Effluent discharge point(s), A=Ambient water station along WOC or one of its tributaries.

Table 12. Water quality and dissolved elements parameters measured by BMAP at 10 sampling stations in the WOC

ANALYSIS	ANALYSIS
Water Quality	**Dissolved Elements**
Alkalinity	Ca
Conductivity	Cu
Hardness	Cr
NH^{+4}	Cd
NO_2	Fe
Total Suspended Solids	Mg
pH	Mn
Soluble reactive P	Na
TOC	Pb
Total P	Si
Total Soluble P	Zn
Temperature	

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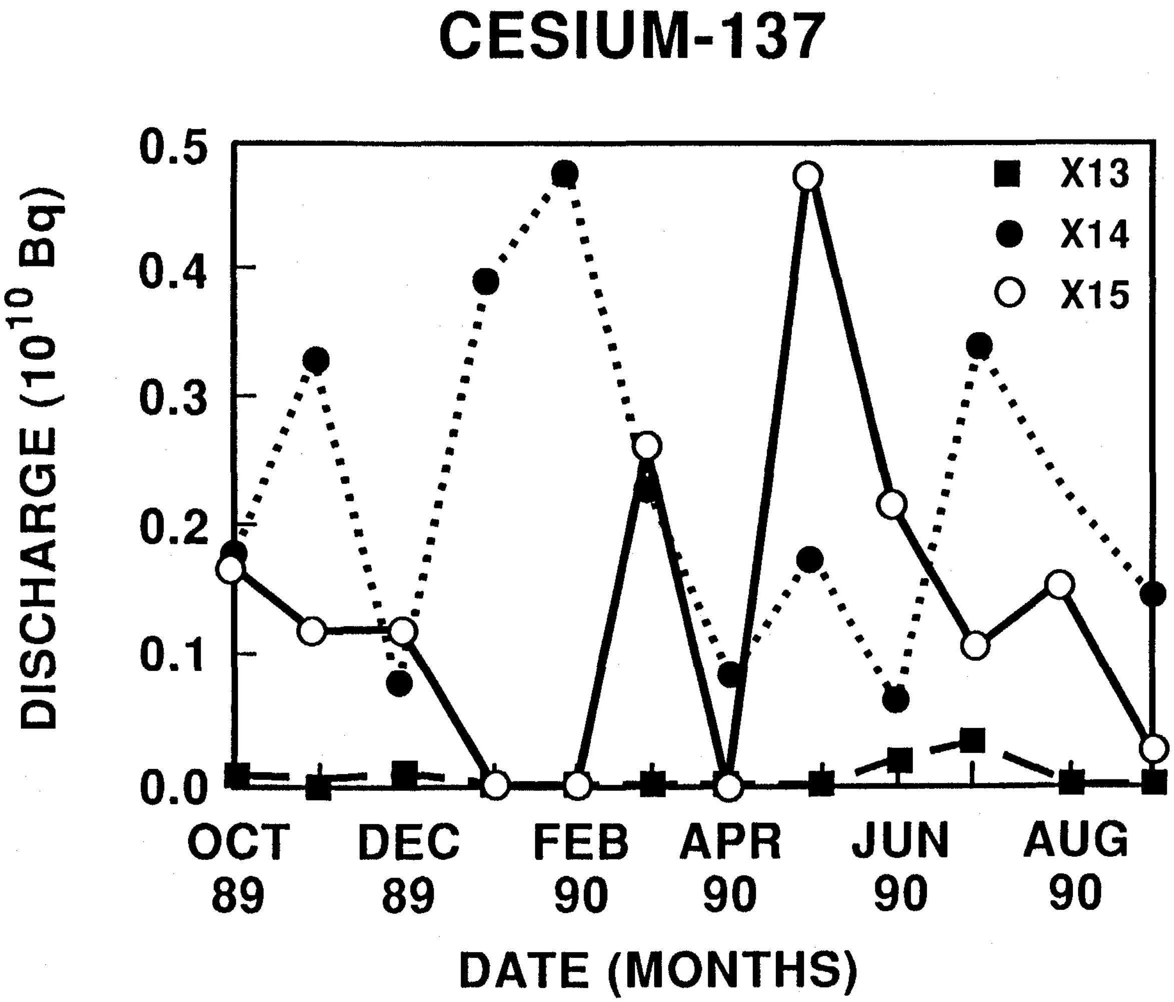

Fig. 24. Concentrations of ^{137}Cs at ESP monitoring stations X13, X14, and X15 during Water Year 1990.

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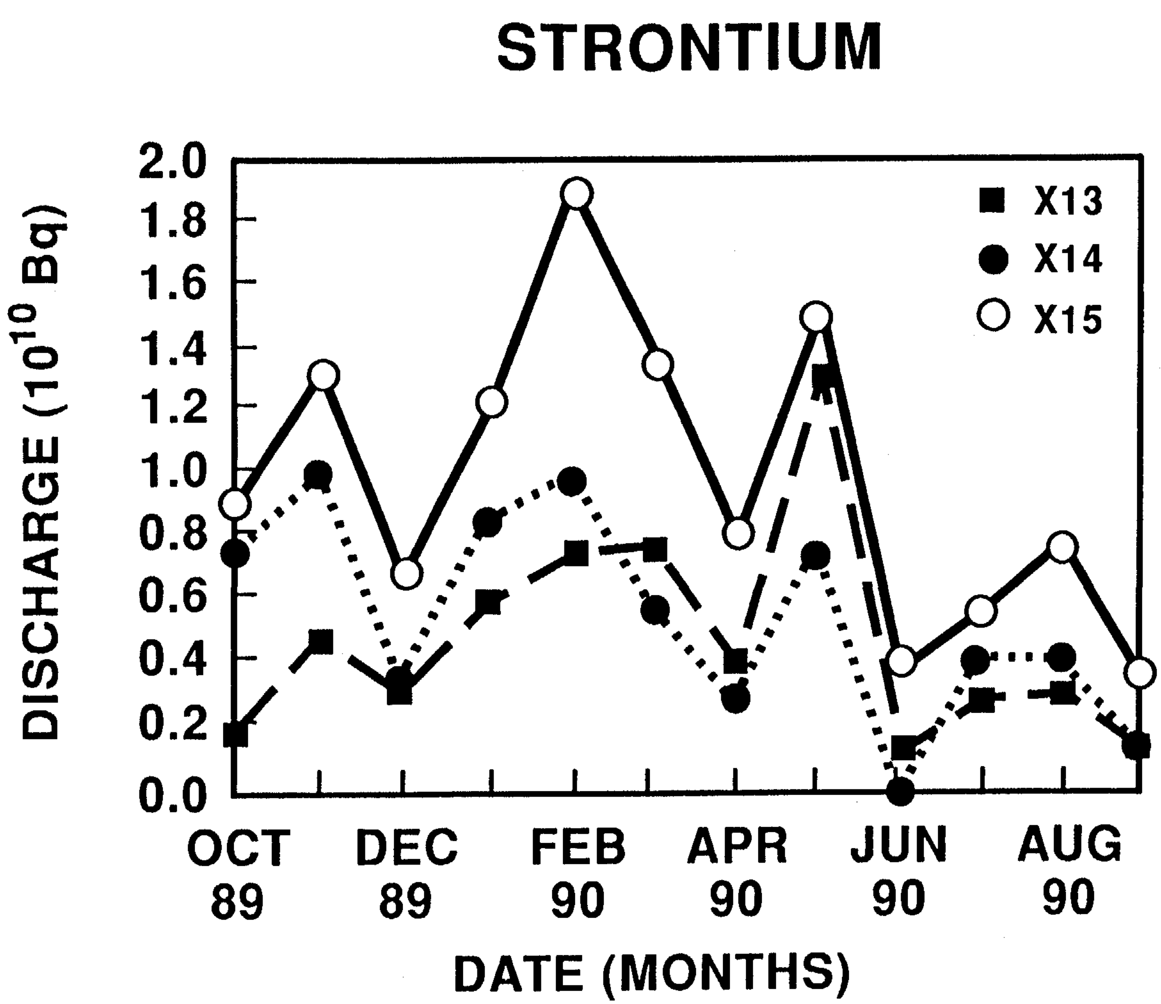

Fig. 25. Concentrations of ^{90}Sr at ESP monitoring stations X13, X14, and X15 during Water Year 1990.

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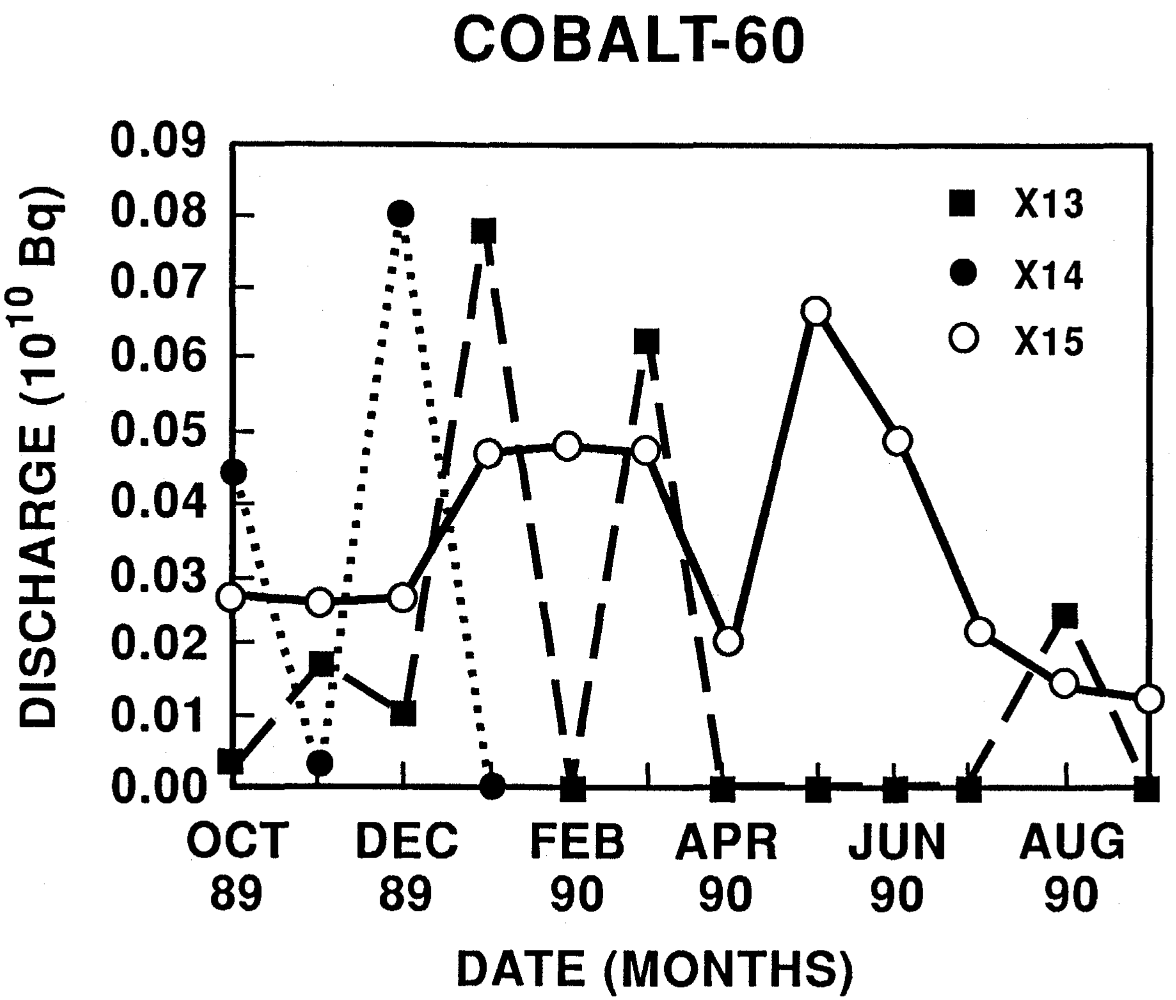

Fig. 26. Concentrations of ^{60}Co at ESP monitoring stations X13, X14, and X15 during Water Year 1990.

ORNL DWG 91Z-14859

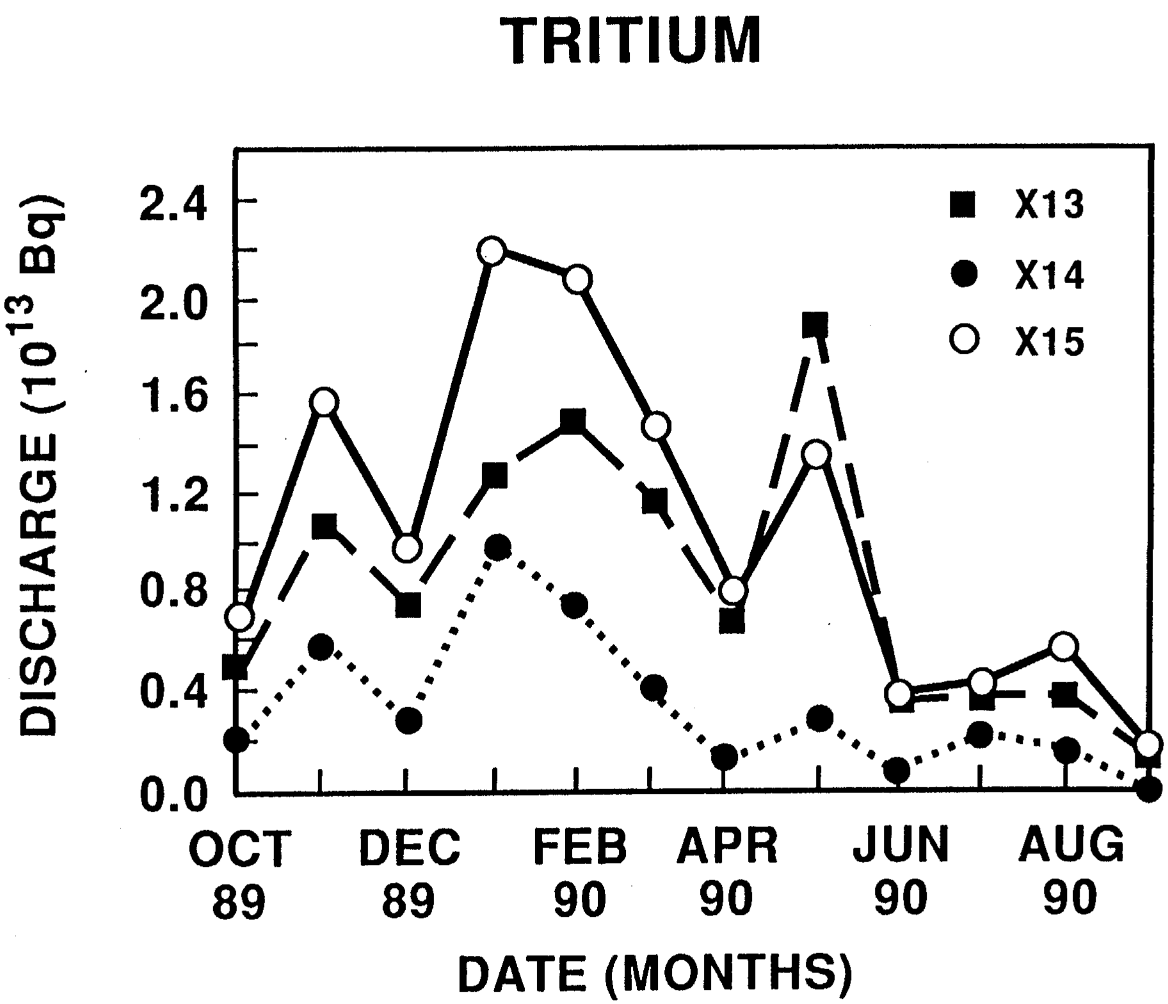

Fig. 27. Concentrations of ^3H at ESP monitoring stations X13, X14, and X15 during Water Year 1990.

Raccoon Creek receives surface runoff and, presumably, groundwater recharge from the western portion of SWSA 3. All other drainage from SWSA 3 is east toward the WOC watershed. This facility was built to complete the Stream Sampling Network necessary to determine the extent of radionuclide migration from ORNL's SWSAs; however, composite sampling is not conducted at this site. ESD's Watershed Hydrology Group collects discharge data at this site, and some evidence of contaminants has been detected in ESP's water quality grab samples collected there.

3.2.3 Contaminants in Sediments

Studies of WOC streambed gravels as indicators of the degree and location of sources of radiological contaminants (Cerling 1985; Cerling and Spalding 1981) were continued during 1986-1987). Internal RAP report(s) released in May 1987 (Cerling et al. 1987) documented the results of studies of new sources of ^{90}Sr and ^{137}Cs in First Creek and upper WOC behind the ORNL main plant. Reports have also been completed on current studies to quantify radionuclide flux at selected sites based on radionuclide and metal concentrations on gravels and the associated streamflow, and to determine the mechanisms and rates of radionuclide and metal sorption and desorption on streambed gravels.

An aerial radiological survey was conducted during September and October of 1986 to provide detailed information on the nature and location of radiological contaminants in floodplain sediments. The study report by EG&G Energy Measurements (Fritzsche 1987) describes the survey methodology and shows detailed contours of total terrestrial gamma exposure rates and activities of ^{137}Cs, ^{60}Co, and ^{208}Th. These four isopleth maps, on aerial photographs of the floodplain, are reproduced here as Figures 28–31.

In August 1989, ESP extensively sampled sediment at the monitoring stations on WOC (MS3) and MB (MS4). Multiple sediment samples were collected from the stilling pool upstream from the weir at MS3, and from the stilling pool upstream from the weir and from sediments downstream from the weir at MS4. Samples were analyzed for radionuclides, metals, and PCBs, partly to characterize the contaminated sediments as a waste for ultimate removal and disposal at a later time. Results of these analyses can be obtained from ESP's Information Integration and Analysis Group.

As part of the Clinch River RFI, sediment sampling was conducted in the WOCE in the summer of 1990. Results of initial core sampling near the mouth of the embayment revealed elevated activities of ^{137}Cs for surface sediments. This finding prompted additional surface sediment and core sampling in the embayment. Subsequent sediment samples were analyzed for a wide range of contaminants including radionuclides, metals, and organics.

3.2.4 Outfalls to the Whiteoak Creek Flow System

Water is supplied to the ORNL plant site from the DOE water treatment plant at an average rate of approximately 4.0 million gallons per day (mgd) [6.19 cfs]. This water is then distributed to ORNL facilities through two separate systems: potable and process. Of the total amount of imported water, approximately 38% is lost to the atmosphere as evaporation. The remaining 62% is subsequently discharged to the WOC surface-water system

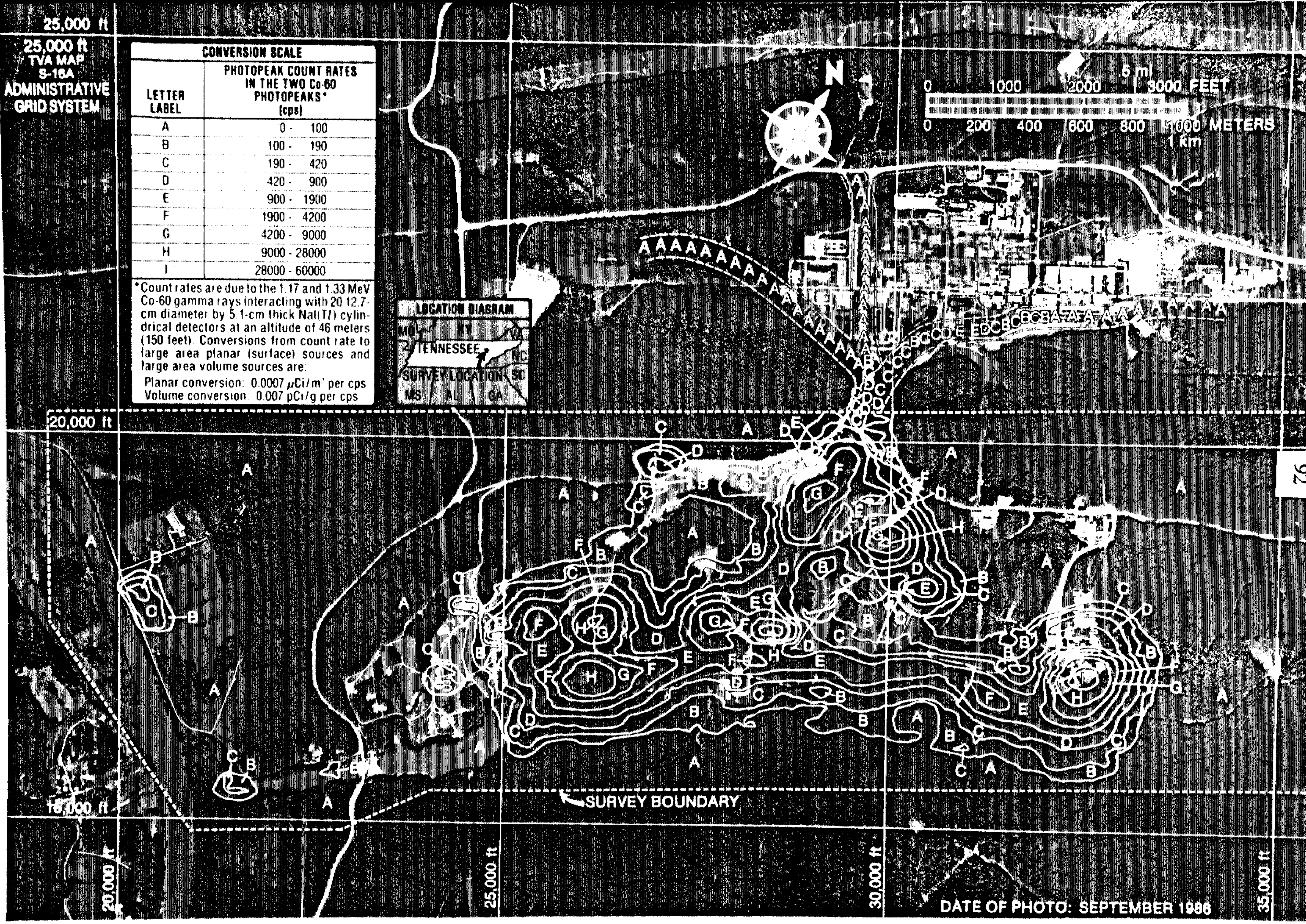

Fig. 29. Cobalt-60 photopeak count rate isopleths derived from the September-October 1986 survey of the Whiteoak Creek floodplain. Source: Fritschze (1987).

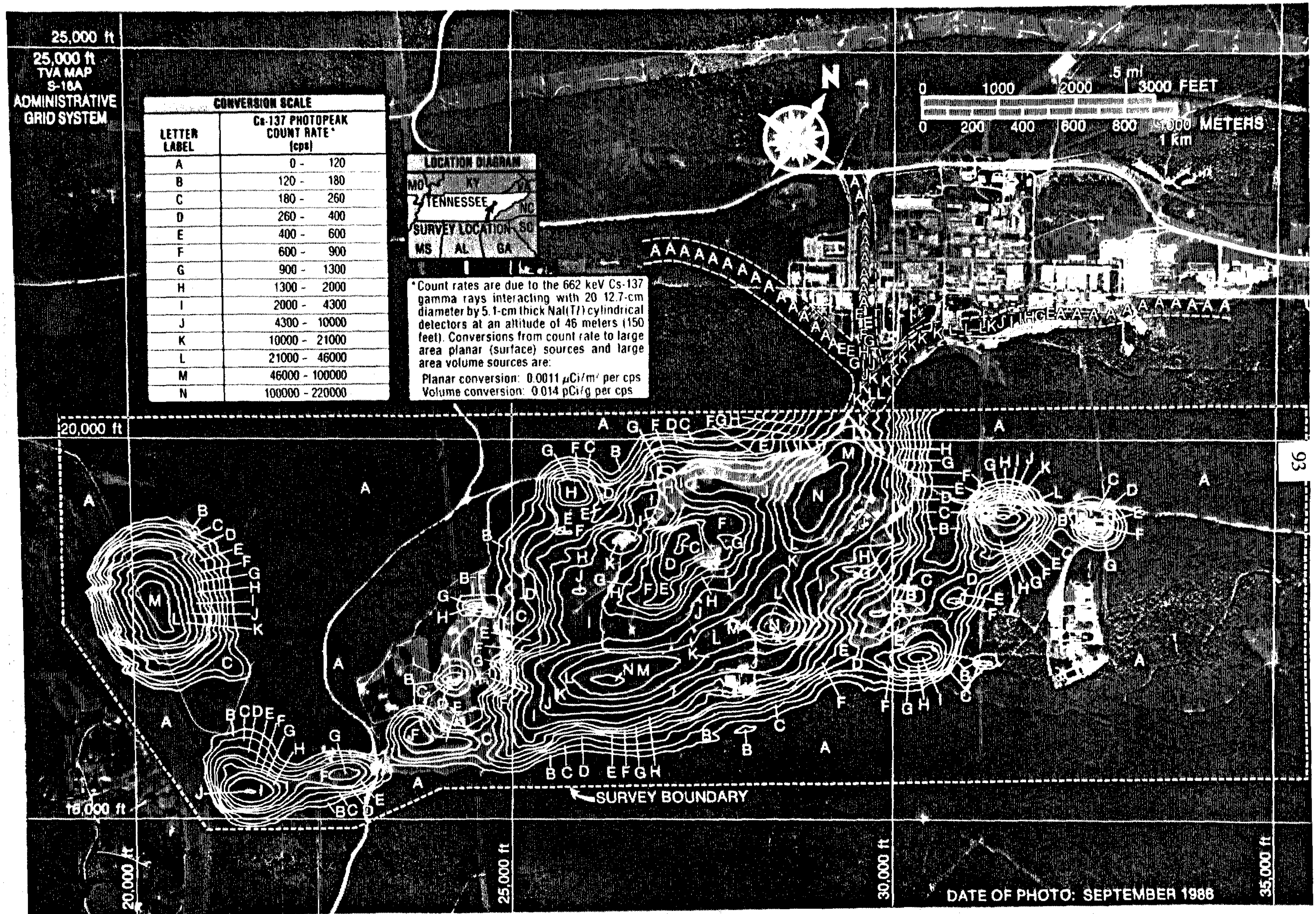

Fig. 28. Cesium-137 photopeak count rate isopleths derived from the September-October 1986 survey of the Whiteoak Crrek floodplain. Source: Fritschze (1987).

Fig. 30. Gamma energy spectra locations derived from the September-October 1986 survey of the Whiteoak Creek floodplain. Source: Fritschze (1987).

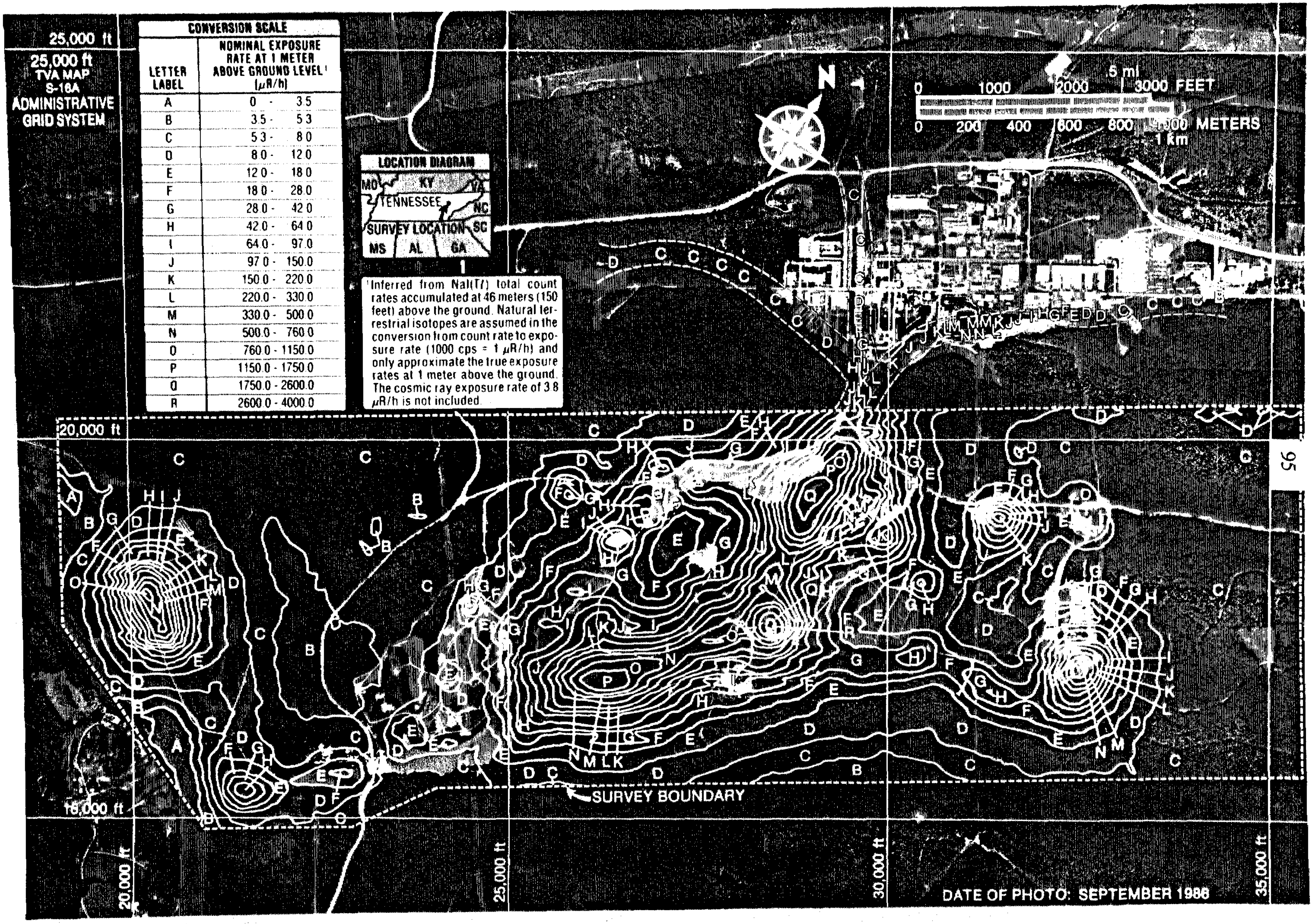

Fig. 31. Terrestrial gamma exposure rates derived from the September-October 1986 survey of the Whiteoak Creek floodplain. Source: Fritschze (1987).

(Kasten 1986). According to Loar et al. (1991), approximately 30% and 36% of the estimated total effluent volume to the WOC system are contributed by the cooling and process systems, respectively. Discharges from the Sewage Treatment Plant (STP), the steam plant, and leakage account for the remainder in approximately equal proportions (Kasten 1986).

Under the requirements of the Clean Air Act, NPDES Permit No. TN0002941 was issued on April 1, 1986 to ORNL to monitor point sources at their point of discharge into receiving streams. In September 1990, ORNL applied for renewal of the NPDES permit, which expired March 31, 1991. ORNL's NPDES permit application is described in Section 1.1.2. Point Source Outfalls are discernible, confined, and discrete conveyances from which a process stream is discharged to receiving waters. The effluent must be monitored before it reaches the receiving water or mixes with any other wastewater stream. The original permit identified at least 176 outfalls.

Ten major effluent discharges (Point Source Outfalls) were regulated under the original permit and accounted for approximately 83% of the water discharged to the WOC system. One additional Point Source Outfall described under the permit was the planned Nonradiological Wastewater Treatment Facility (NRWTF), NPDES outfall No. X12. This facility went into service in February 1990. The facility was built to collect, transfer, store, and treat the laboratory's nonradiological wastewaters according to nationally specified criteria. The NRWTF (X12) has combined the treatment of effluents from, and replaced, the following eight outfalls: 1500 Area (X03), 2000 Area (X04), 190 ponds (X06), Process Waste Treatment Plant (X07), TRU ponds (X08), HFIR ponds (X09), ORR Resin Regeneration Facility (X10), and the Acid Neutralization Facility (X11). Therefore, there are now only three major, treated effluent discharges that enter WOC: the STP (X01), the Coal Yard Runoff Treatment Facility (CYRTF) (X02), and the NRWTF (X12) (see Table 13).

Table 13. Major treated effluent discharges to Whiteoak Creek from ORNL.

NPDES OUTFALL NO.	EFFLUENT SOURCE	AVERAGE DISCHARGE
X01	Sewage Treatment Plant	0.34 cfs[a]
X02	Coal Yard Runoff Treatment Facility	0.048 cfs[b]
X12	Nonradiological Wastewater Treatment Facility	0.62 cfs[c]
	TOTAL	1.008 cfs

[a]The maximum flow rate is 1.16 cfs.
[b]The maximum flow rate is 0.34 cfs.
[c]Estimated.

Additional outfalls to the WOC system are divided into five categories (Category I, Category II, Category III, Cooling Water, and Miscellaneous Source Discharges) according to effluent limitations and monitoring requirements.

Outfalls which discharge uncontaminated stormwater runoff are designated as Category I outfalls. Each Category I outfall is identified by a 100 series number or a 300 series number, indicating a Category III outfall that has been reassigned as Category I.

Category I originally consisted of 35 discharge pipes installed to control precipitation runoff at ORNL. These storm drains discharge uncontaminated storm water to WOC, First Creek, Fifth Creek, MB, and the Bearden Creek embayment (outside the WOC watershed). All Category I outfalls are listed in the current NPDES permit. Ten additional outfalls have been added to this category due to the reclassification of some Category III outfalls. All Category I outfalls are depend on precipitation and are monitored annually, during or immediately following a rainfall. Most of the Category I outfalls have been monitored for pH, oil and grease, total suspended solids, and gross beta.

Category II outfalls discharge water from roof drains, parking lot runoff, storage area drains, spill-area drains, once-through cooling water, cooling tower blowdown, and condensate. Numerous Category II outfalls receive contributions from several of these sources. Each Category II outfall is identified by a 200 series number or a 300 series number, indicating a Category III outfall that has been reassigned as Category II.

Category II originally consisted of 62 discharge pipes installed for controlling precipitation runoff, non-contact cooling water, cooling tower blowdown, and condensate drains. These outfalls discharge to WOC, First Creek, Fifth Creek, MB, and Melton Hill Lake. All Category II outfalls are listed in the current NPDES permit. Fourteen additional outfalls have been added to this category due to the reclassification of some Category III outfalls. All of these outfalls are monitored quarterly. Most of the Category II outfalls have been monitored for pH, oil and grease, total suspended solids, and gross beta. Table 14 summarizes the Category I and II outfalls at ORNL.

Category III outfalls were allowed by the 1986 NPDES permit to discharge unpermitted process and laboratory wastewater until treatment facilities became operational. This refers primarily to the NRWTF. Category III outfalls were eliminated as of March 31, 1990, soon after the NRWTF went on line. All of these outfalls have either been proposed for reclassification as Category I or II outfalls or have been eliminated by diverting them to treatment facilities in order to eliminate untreated discharges, reduce pollutant concentrations, and/or plug the outfall discharge pipe. Of the 32 outfalls previously classified as Category III, 10 have been reclassified as Category I, 14 as Category II, and the remaining 8 have been physically eliminated by stopping the discharge and plugging the discharge pipe or rerouting the discharge to a permitted treatment facility. The characterization, elimination, and reclassification of Category III outfalls is described in the NPDES permit application for renewal.

The ORNL Space Cooling System consists of major and minor cooling towers and numerous once-through, non-contact cooling systems. The total cooling water discharge to

Table 14. Summary of Category I and II outfalls at ORNL. Category II outfalls have been subdivided into smaller drainage/runoff units.

Category	Location	Subtotal	Total
I	Whiteoak Creek		16
I	First Creek		8
I	Fifth Creek		16
I	Melton Branch		4
I	Bearden Creek Embayment		1
II	Whiteoak Creek:		42
II	Parking Lot Runoff	20	
II	Condensate	6	
II	Non-contact Cooling Water/Parking Lot Runoff	13	
II	Cooling Tower Blowdown	2	
II	Spill Area Drain	1	
II	First Creek:		10
II	Parking Lot Runoff	7	
II	Storage Area Drain	2	
II	Non-contact Cooling Water/Parking Lot Runoff	1	
II	Melton Branch:		5
II	Parking Lot Runoff	4	
II	Cooling Tower Blowdown	1	
II	Fifth Creek:		18
II	Spill Area and Storage Area Drains	3	
II	Parking Lot Runoff	7	
II	Non-contact Cooling Water/Parking Lot Runoff	2	
II	Condensate	4	
II	Cooling Tower Blowdown	2	
II	Melton Hill Lake:		1
II	Cooling Tower Blowdown	1	

WOC is estimated to be approximately 1.65 MGD (2.55 cfs). These discharge flows are made up primarily of cooling tower blowdown and once-through cooling water.

ORNL has 9 major and 18 minor cooling towers for removing heat from facility cooling waters. Each of the major cooling towers discharge over 10,000 gallons per day (gpd) of blowdown while minor cooling towers discharge less than 10,000 gpd. In addition, major cooling towers may have occasional high concentrations of chlorine, copper, and/or zinc, whereas the discharge from minor cooling towers is not expected to applicably lower water quality. The total discharge from all cooling towers is about 0.25 mgd (0.39 cfs).

Discharge from the once-through, non-contact cooling water systems amounts to about 1.4 mgd (2.17 cfs). All ORNL once-through cooling water is supplied by the DOE Water Filtration Plant and is therefore chlorinated. ORNL has a policy that all new sources of once-through cooling water will be dechlorinated prior to being discharged. Initially, these dechlorination systems will be installed on a few outfalls to test the system for further development and refinement. Dechlorination systems will eventually be installed on all applicable outfalls.

Miscellaneous source discharges have not been identified in the NPDES permit as a serial numbered discharge. Each is specific to a special category identified by the EPA. Limitations have been placed on all Miscellaneous Source Outfalls. Boilers, Vehicle and Equipment Cleaning Facilities, Painting and Corrosion Control Facilities,Petroleum Storage and Handling Areas, Vehicle and Equipment Maintenance Facilities, Battery Rework Facilities, Photographic Laboratories, Firefighter Training Areas, the Hillcut Disposal Facility, and Non-contaminated Wastewater Holding Ponds are in this category. The NPDES permit renewal application describes each of these facilities and locates its source of discharge.

3.3 GROUNDWATER

Subsurface materials near ORNL can be hydrologically classified into a near-surface stormflow zone, a vadose (unsaturated) zone, and a groundwater zone (Fig. 32). The stormflow zone approximately corresponds with the root zone of vegetation and is much more permeable than the vadose zone (Moore 1989). Many rainfall events produce a transient, perched water table in the stormflow zone, and water is then transmitted downslope to nearby streams. The stormflow zone extends to a depth of about 0.2–2.0 m, and water storage is intergranular. Total porosity is about 0.30–0.50 (Davis et al. 1984; Peters et al. 1970). Hydrograph analysis in the forested headwaters area of Melton Branch shows that the specific yield of the stormflow zone is about 0.035; the average hydraulic conductivity is about 9.0 m/d; the peak discharge rate to streams is about 80 L/s km^2 of drainage area; and the capacity for transient water storage (the amount of water to be discharged during drainage) is about 20,000 m^3/km^2 (Moore 1991). The stormflow zone is filled during rainfall events and is nearly drained 5–15 d afterwards.

In the vadose zone, water percolates downward from the stormflow zone to the groundwater zone (Fig. 32). The permanent water table is near the regolith and bedrock contact at depths of about 1–10 m. Rainfall recharges the water table (Stockdale 1951). Between a few hours and 45 d after a precipitation event; the average delay is about 4 d

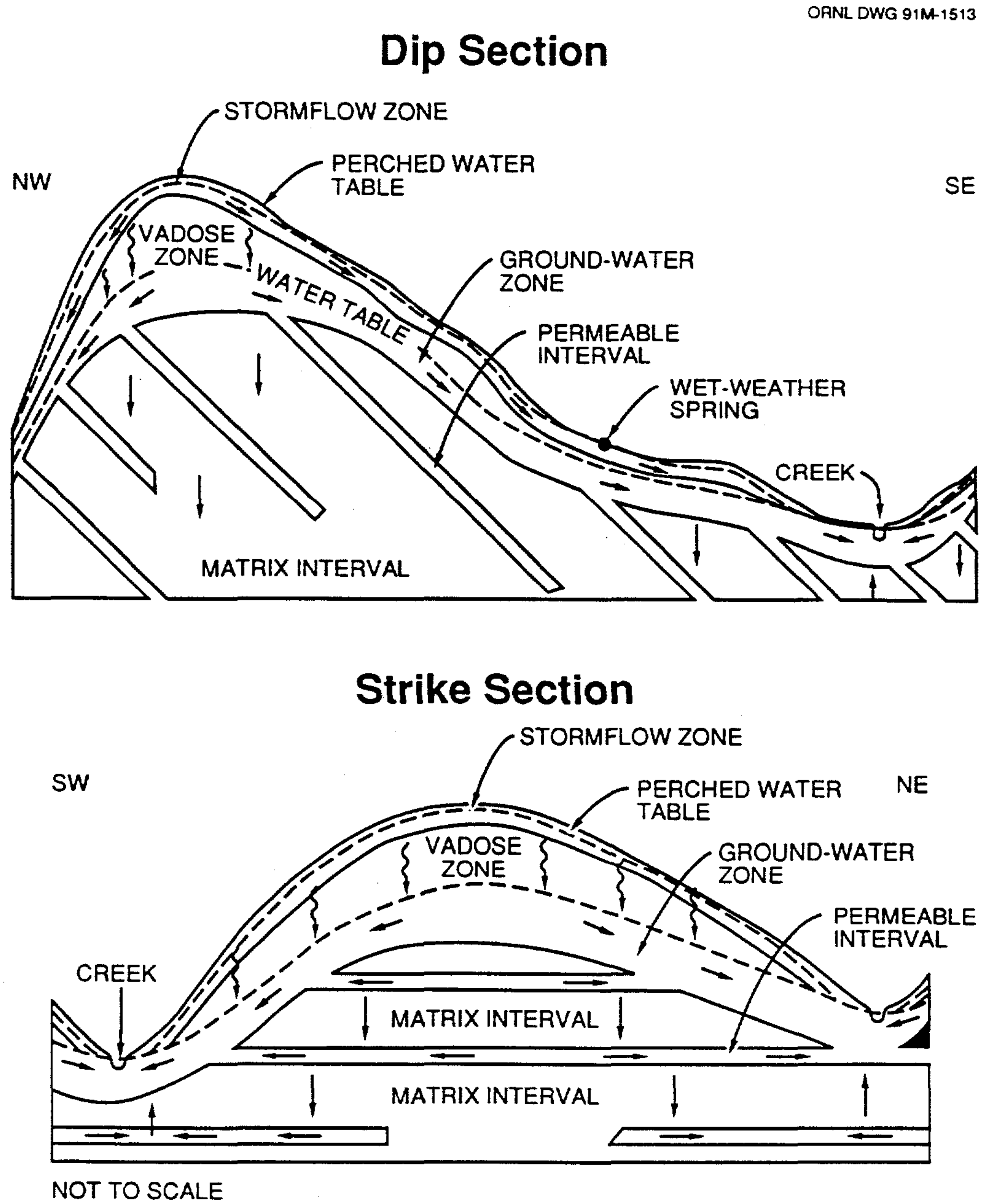

Fig. 32. Sections showing hydrogeologic zones and directions of water flow on the Oak Ridge Reservation.

(Moore 1989). The stormflow and groundwater zones are connected near streams and may be connected, in some areas, on steep hillslopes.

In the groundwater zone, a layer where permeable fractures are connected in three dimensions occurs near the water table. At deeper levels, a few permeable fracture intervals occur within a relatively impermeable matrix (Fig. 32). Fifteen tests with an electromagnetic borehole flowmeter showed that the average thickness of the permeable intervals is about 60 cm. Well logs and an analysis of the depths of paired shallow and deeper wells shows that the vertical spacing between permeable intervals increases from 7 m near the water table to >35 m at depths below 60 m. The average hydraulic conductivity of the permeable intervals (0.4 m/d) is two to three orders of magnitude larger than that in the matrix intervals (Moore 1991). Under these conditions, lateral flows of groundwater toward nearby streams occur only in the permeable intervals, and flows in the matrix intervals follow tighter nearly vertical fractures.

Hydrograph analysis in the headwaters area of Melton Branch shows: (1) most groundwater flows to the streams through the permeable layer just below the water table, (2) specific yield near the top of the groundwater zone is about 0.0025, (3) the peak discharge rate to streams is about 4.7 L/s km^2 of drainage area, and (4) the capacity for transient water storage during an average year is about 3,400 m^3/km^2 (Moore 1991). Contours of water table elevation at the time of high and low water levels in wells show little change in hydraulic gradient. Increases and decreases in the groundwater discharge rates to streams are caused mostly by changes in saturated thickness and thus by changes in the transmissivity of the permeable layer near the water table. This layer is partly to nearly drained between rainfall and recharge events.

Hydrogeologic data acquired during the period of this report (1988–90) result from (1) continuous monitoring of water levels and partial analyses of waters in stormflow monitoring tubes during part of 1990, (2) measuring selected aquifer characteristics, (3) construction of compliance and water quality monitoring wells for RCRA and CERCLA purposes, (4) monthly measurements of water level and in situ measurements of temperature and specific conductance of waters in selected observation wells, and (5) quarterly measurements of water levels and analyses of water samples from WAG perimeter wells in support of the ERP.

3.3.1 Stormflow Monitoring

Stormflow monitoring tubes (Fig. 33) were installed at 17 locations (Fig. 34) in the headwaters area of Melton Branch. Water levels were monitored, and water samples were collected during part of 1990. All monitoring tubes had water inflows during some rainfall events, indicating a perched water table. Monitoring tubes on steep slopes and in gullies generally had water inflows during small events, whereas larger or more intense events were required to produce inflows to tubes near a drainage divide or on shallow slopes. Water levels in the stormflow monitoring tubes peak within 1–3 h of greatest rainfall intensity during the non-growing season. There are fewer water level responses and more delayed responses during the growing season because the soil is replacing larger water deficits.

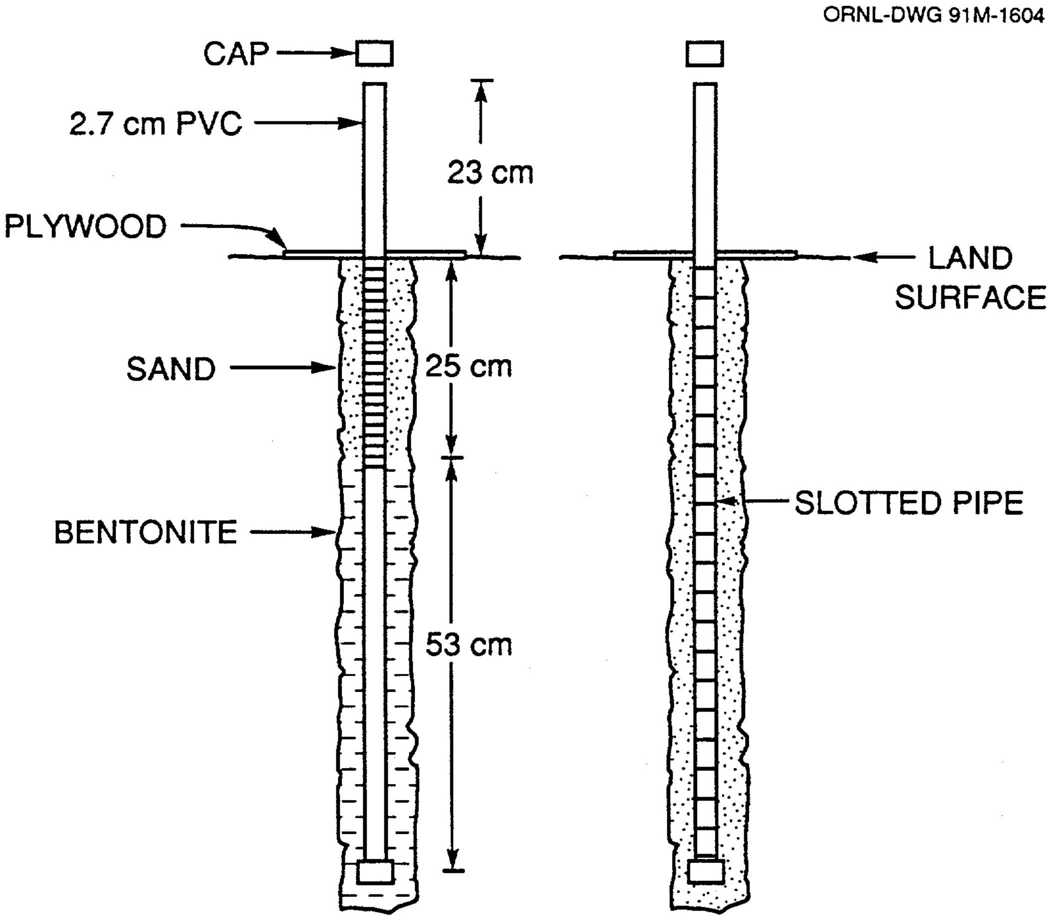

Fig. 33. Construction diagrams of tubes used for collection of water samples (left) and for monitoring of water levels (right) in the stormflow zone.

ORNL DWG 90M-1786

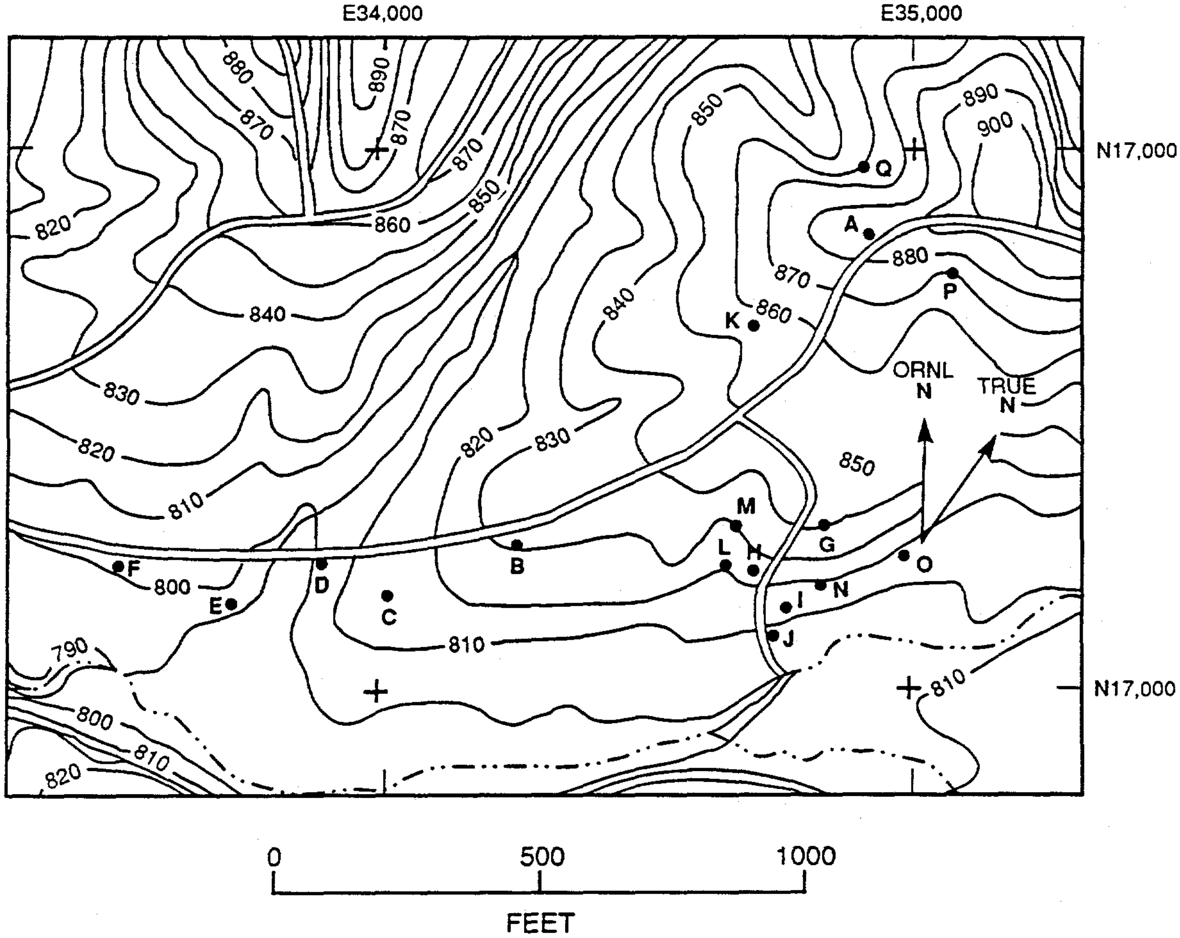

Fig. 34. Locations of stormflow monitoring tubes in the headwaters area of Melton Branch.

During the non-growing season, graphs of log water-level stage in the stormflow zone vs time plot as straight lines soon after the hydrograph peak (Fig. 35). Similarly, a plot of log streamflow rate vs time forms a straight line after the end of overland runoff. The average slope (B=0.015/h) of this line is approximately the same as that of the average stage recession in the stormflow monitoring tubes. After several more days of recession, the streamflow data plot as a curve and then plot as a straight line with an average slope (B=0.0050/h) that is nearly the same as that of the average water level recession in observation wells. The close correspondence of the semilog recession rates shows that nearly all streamflow at high base flows is produced by discharge from the stormflow zone, whereas discharge from the groundwater zone is dominant at lower base flows, after the stormflow zone has drained. During the growing season, graphs of water level recession in the stormflow zone plot as a steepening curve because water is consumed by evapotranspiration (Fig. 36). The streamflow recession slopes are also much steeper and occur sooner than do stage recessions in the stormflow zone. These hydrographs apparently show that the water table drops below the stream channel during the growing season, that there is little or no discharge of subsurface waters to streams, and that natural streamflow during the growing season is nearly all overland flow from wetland areas. Lateral flows of water in the stormflow zone and the groundwater zone continue, and these flows may cause an accumulation of contaminants in some riparian areas.

All water samples from the stormflow monitoring tubes in the headwaters area of Melton Branch were cloudy to muddy, and a large majority of the suspended sediment was colloidal in size. The concentration of suspended sediment was not measured and probably was small. Nevertheless, the discharge of colloidal material from the stormflow zone may explain some of the turbidity in high base streamflows. Also, some pollutants could be sorbed by these colloids in contaminated areas and thereby transported to the streams.

Water in the stormflow zone is slightly acidic. The arithmetic mean of 150 measurements of pH is 5.8, and the range from the mean $\pm$ 1 SD (standard deviation) is 5.2–6.5. The water is a calcium bicarbonate type and has smaller concentrations of magnesium, sodium, and (probably) sulfate. Data for about 200 water samples from stormflow monitoring tubes in the Melton Branch headwaters area show that the concentrations of chemical constituents are lognormally distributed. The geometric mean of total hardness, as $CaCO_3$, is 41 mg/L, the geometric mean of total alkalinity, as $CaCO_3$, is 48 mg/L, and the geometric mean of specific conductance is 109 μmhos/cm at 25 °C. For 80 water samples, the geometric mean of calcium concentration is 12 mg/L, the geometric mean content of magnesium is 2.4 mg/L, and the geometric mean of sodium content is 1.5 mg/L. Other constituents of the water samples were not determined.

3.3.2 Aquifer Characteristics

The depth and vertical extent of water-producing fractures in the rocks cannot easily be determined with conventional procedures. A sensitive electromagnetic borehole flowmeter, newly invented by the Tennessee Valley Authority (TVA), solves to this problem by measuring the vertical flow of water within a screened or openhole interval while water is pumped from or injected into the well. Changes in the flow rate between one depth and another indicate permeable fractures within the interval. Excellent results were obtained from surveys of selected piezometer wells using a prototype instrument.

ORNL DWG 91M-1529

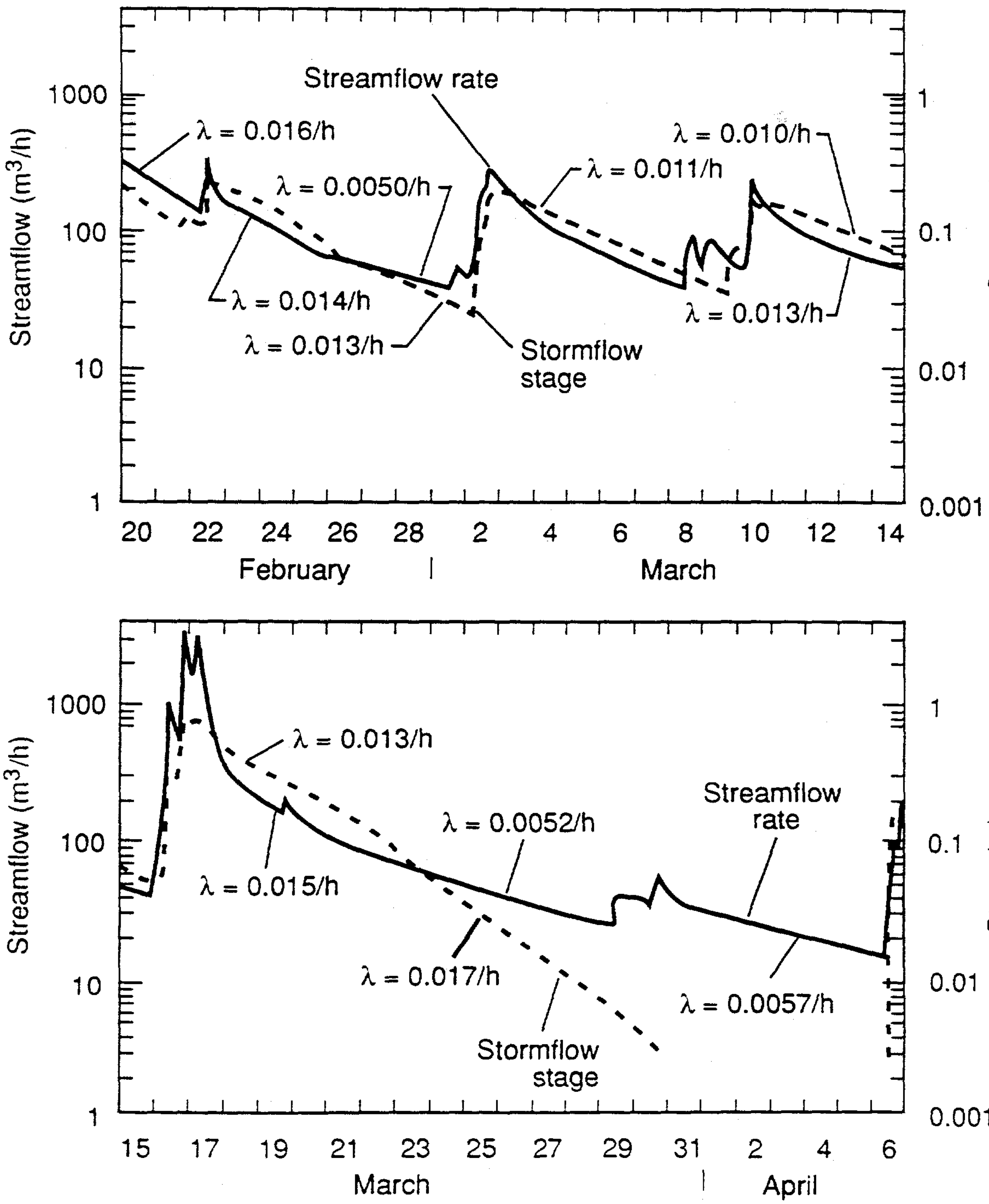

Fig. 35. Hydrographs of streamflow in Melton Branch and composite average water level stage in stormflow monitoring tubes during part of the 1990 nongrowing season; recession slopes (B) are shown in units of inverse time.

ORNL DWG 91M-1530

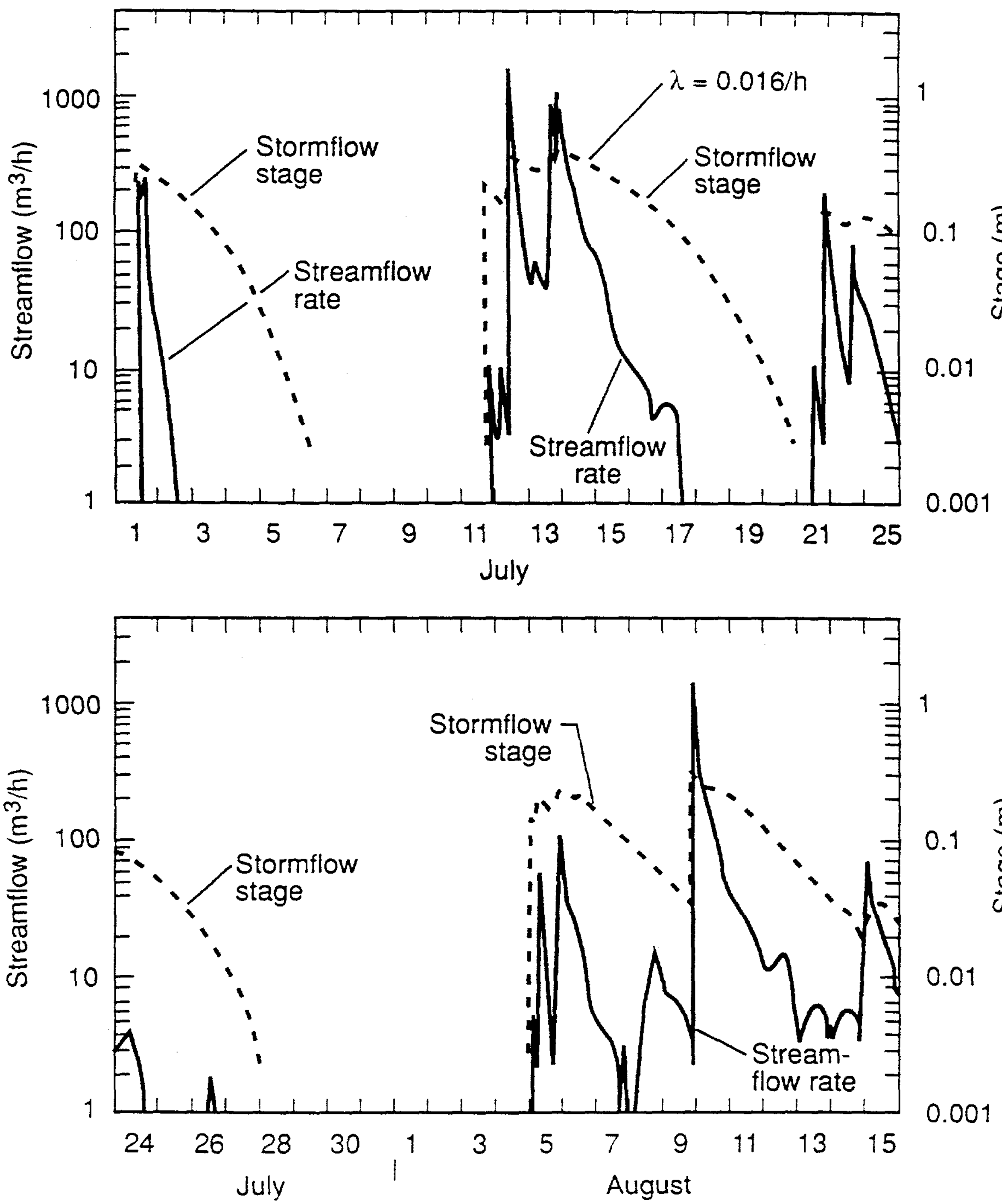

Fig. 36. Hydrographs of streamflow in Melton Branch and composite average water level stage in stormflow monitoring tubes during part of the 1990 growing season.

Piezometer well 703, for example, is screened at depths of 18–24 m, but the flowmeter survey showed that only water-producing fractures occur at depths of 23.2–23.8 m (Fig. 37). Also, construction data for well 575 indicate a well screen at 3.0–4.6 m below land surface. The borehole flowmeter survey, however, showed that the well screen is at depths of 1.8-3.4 m and that the only permeable fractures occur at depths of 1.8-2.4 m (Fig. 37). Most surveys showed that water-producing fractures have a vertical extent of 0.5–1.0 m. An exception is well 705, where the fractures intercept a 2.4 m length of the screen and are nearly equally permeable across the interval (Fig. 37).

Additional data on the transmissivity of the fractured rocks have been obtained during the period of this report. Most new data result from slug tests on wells near the Oak Ridge Y-12 Plant and on new RCRA and CERCLA monitoring wells near ORNL. A cumulative probability graph of all available data (Fig. 38) shows two lognormal populations. The population at the upper right on the graph represents permeable intervals, and the geometric mean of transmissivity is 0.23 m^2/d. The population at the lower left represents matrix intervals, and the geometric mean of transmissivity is 0.0011 m^2/d. If the borehole flowmeter surveys are interpreted to show that permeable intervals have an average thickness of 0.60 m, and if the matrix intervals are assumed to be uniformly relatively impermeable, then the hydraulic conductivity of the permeable intervals is more than 1000 times larger than that of the rock matrix.

New storativity data, mostly from aquifer tests near the Oak Ridge Y-12 Plant, have also been obtained. A cumulative probability graph (Fig. 39) of all available data shows a lognormal distribution. The geometric mean of storativity is 0.00084, and this value is only slightly smaller than the calculated specific yield of 0.0025, as described above. These results suggest that specific yield, effective porosity, and storativity are nearly the same in the fractured rocks of the Oak Ridge Reservation.

3.3.3 Groundwater Quality

The long-term study of groundwater quality which began with early ORNL operations was greatly intensified by Remedial Action Program studies. The RAP studies included regulatory monitoring, scoping studies, and site investigations. Scoping surveys for which data are included in the DIMS were conducted by R. Ketelle in the main plant area (WAG 1) and SWSA 3 (WAG 3), by D. McCrackin in the WOC floodplain, and by L. Toran in the pits and trenches area (WAG 7), SWSA 6 (WAG 6), and near WOL in WAG 2. Ketelle and McCrackin collected unfiltered samples from piezometers for chemical and radiological analyses. The results of the scoping surveys provide only estimates of contaminant levels in the water because of the effects of suspended materials in the samples. However, the results have been useful in planning the locations of water quality monitoring wells and in conducting additional groundwater studies. The distribution of gross beta, gross alpha, ^3H activity, and VOCs in wells in the ORNL main plant area (WAG 1) is shown in Figures 40-41. Gross beta activity in excess of 50 pCi/L, gross alpha in excess of 20 Pci/L, tritium in excess of 1000 Pci/L, and VOCs in excess of 50 μg/L indicate areas where groundwater may be contaminated.

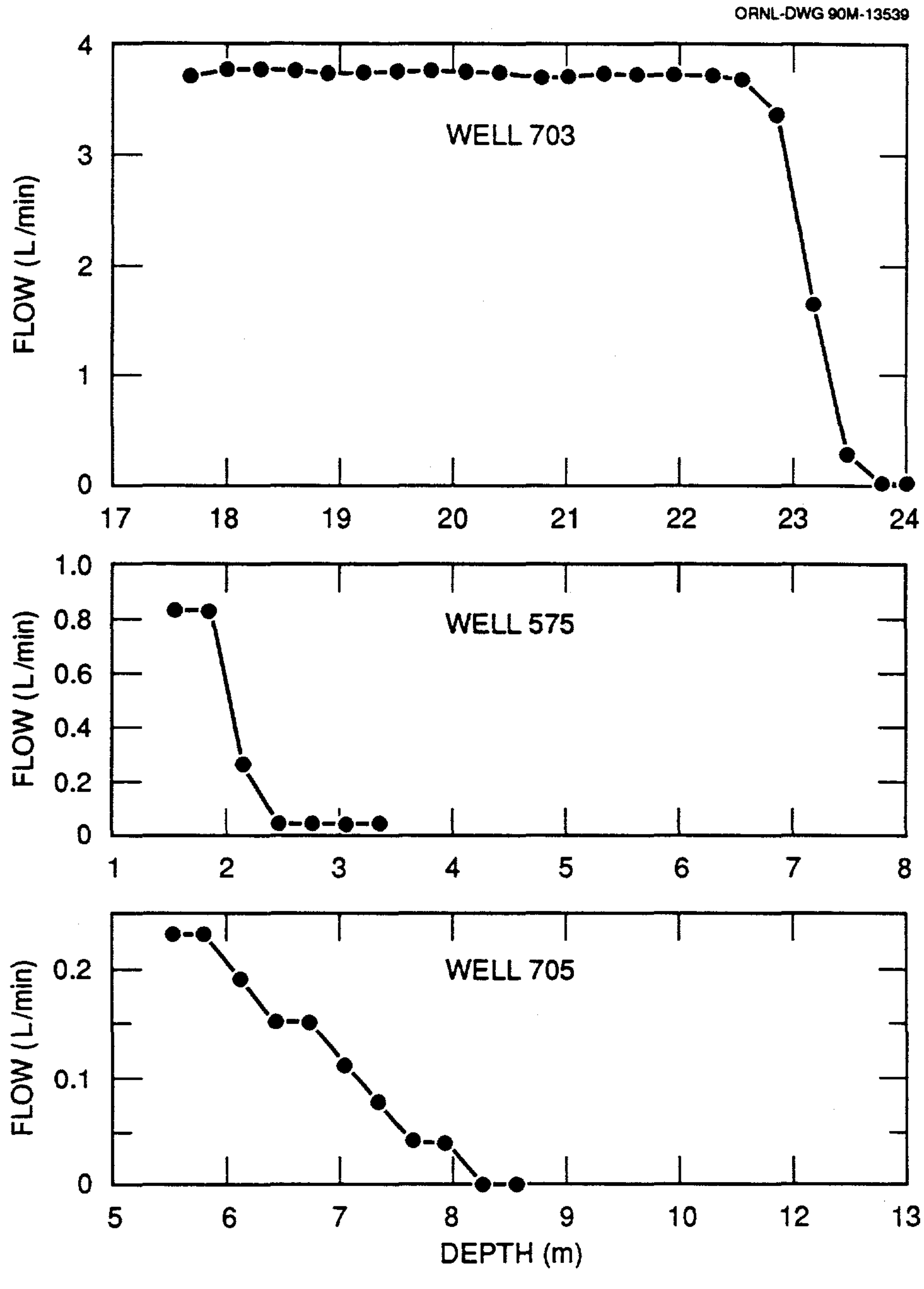

Fig. 37. Peizometer well surveys with an electromagnetic borehole flowmeter indicate impermeable fractures at depths where there are changes in the rates of vertical flow.

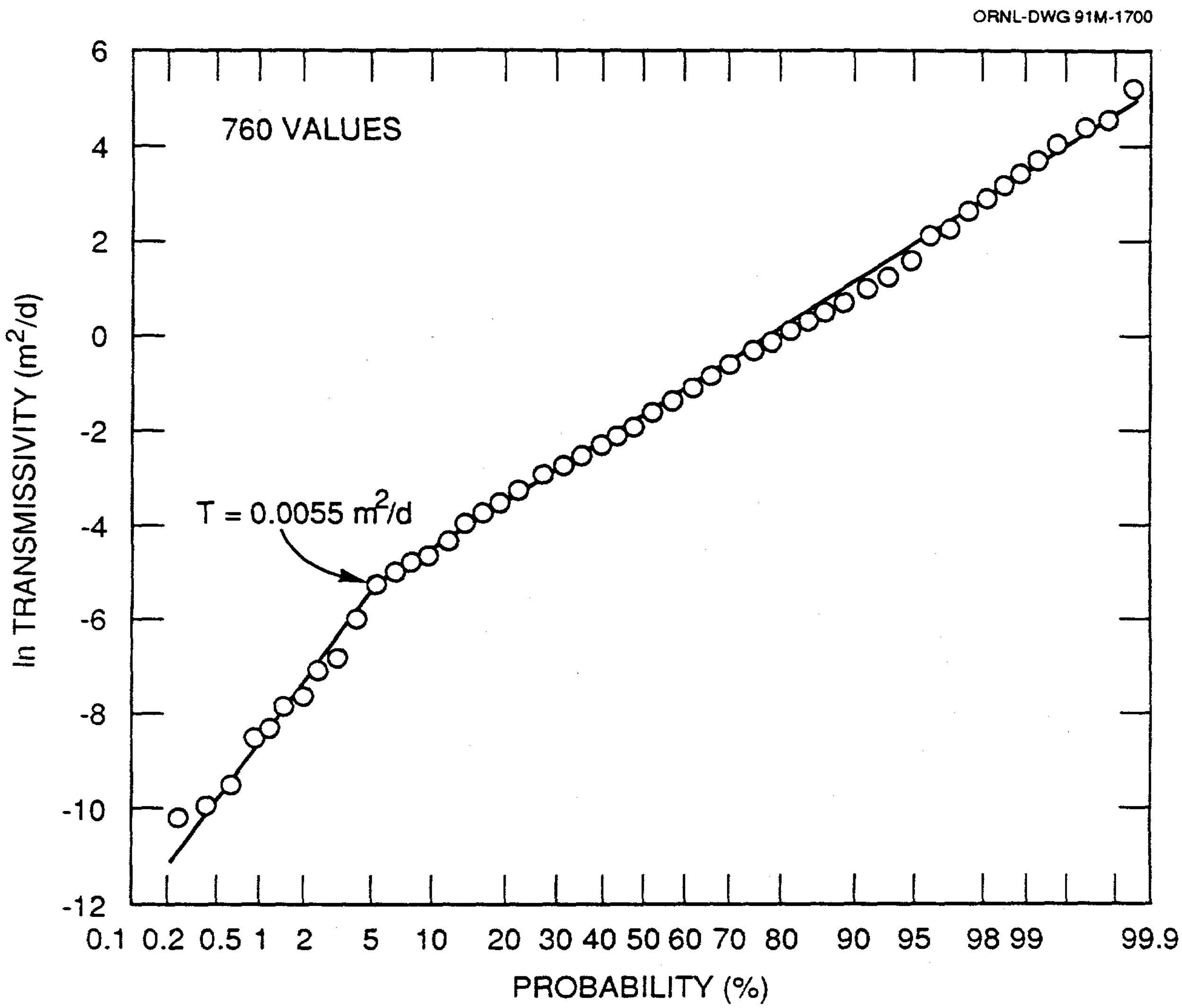

Fig. 38. Cumulative probability graph of transmissivity data from aquifer tests.

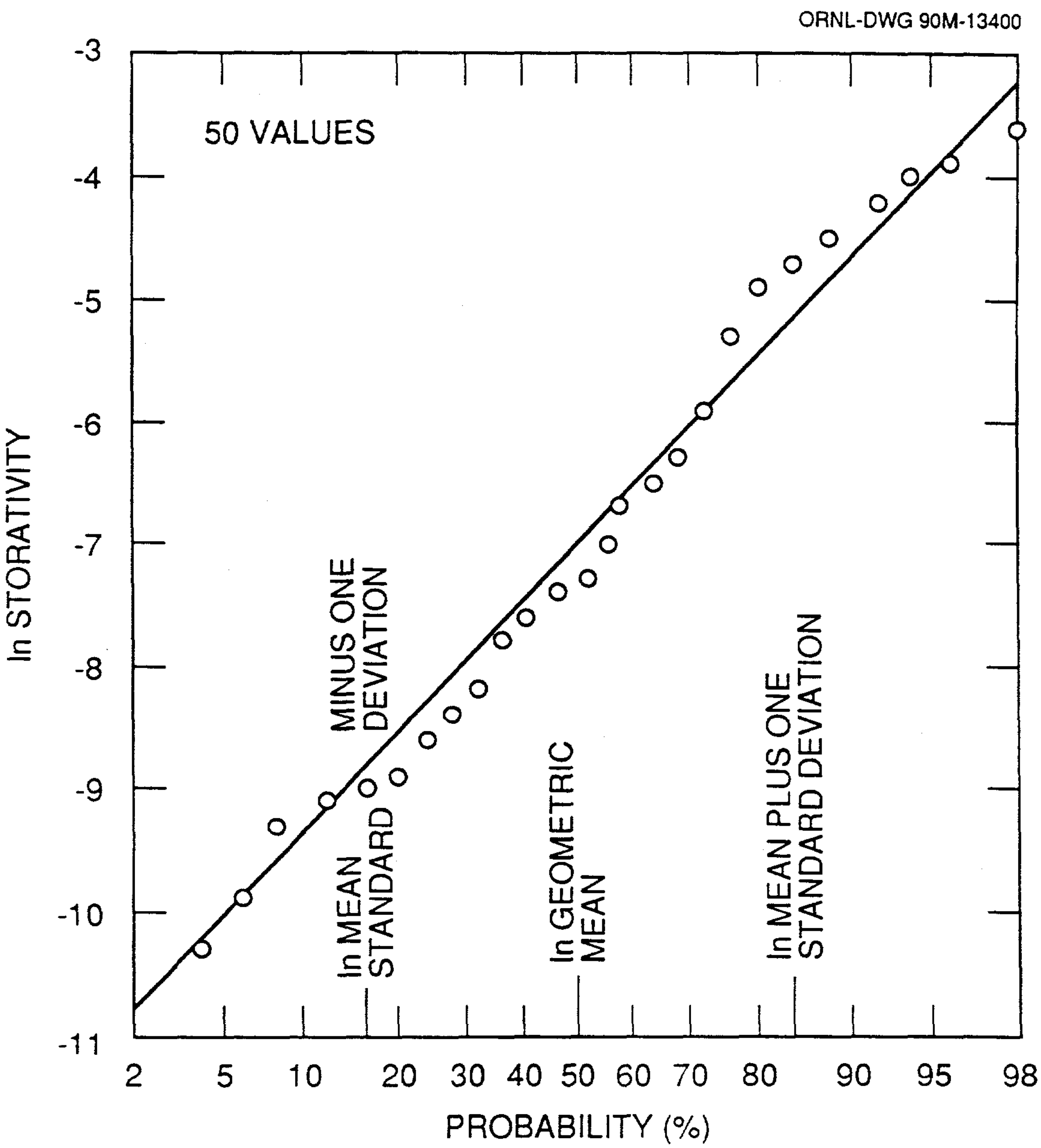

Fig. 39. Cumulative probability graph of storativity data from aquifer tests.

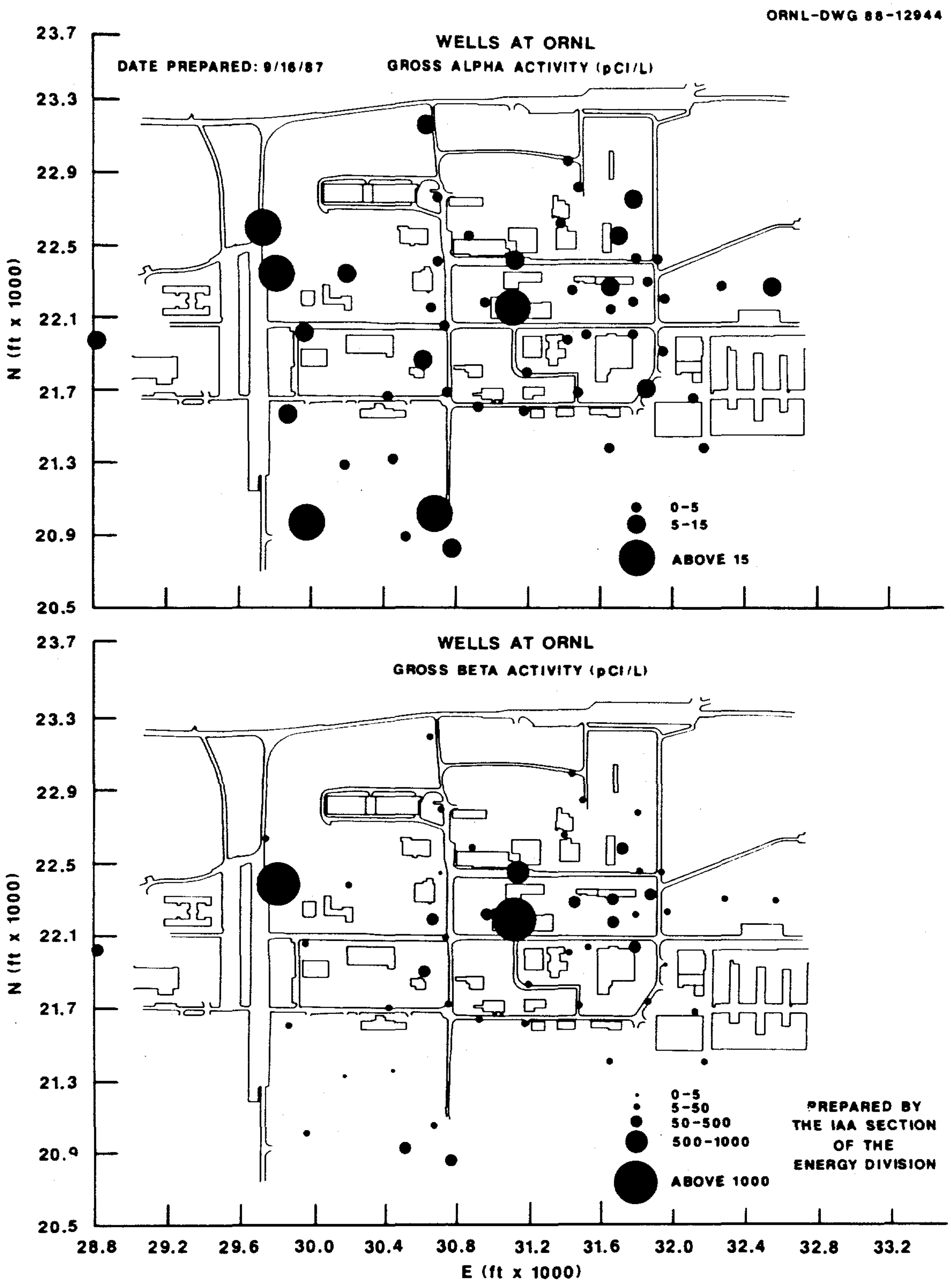

Fig. 40. Distribution of radionuclides in water samples from piezometer wells (a) gross alpha and (b) gross beta activity.

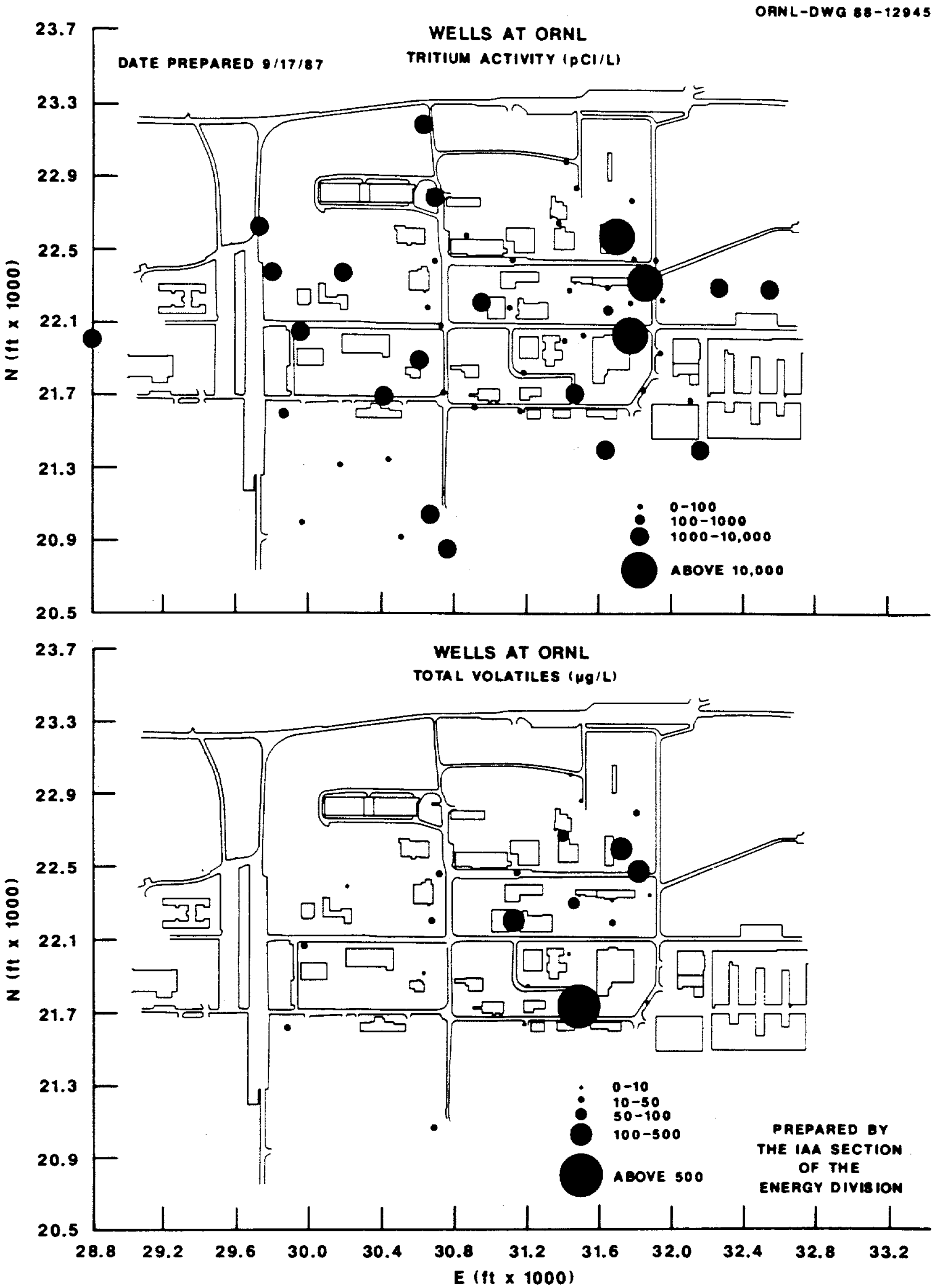

Fig. 41. Distribution of radionuclides in water samples from piezometer wells (a) tritium and (b) total volatiles activity.

The results of the scoping survey in the WOC floodplain indicate that shallow groundwater has been affected by radiological and chemical contaminants in the effluent from long-term operation of the ORNL facilities as well as by leachates from upgradient solid and liquid waste disposal areas. Radiological activity levels were above background in many piezometers. Levels of ^{3}H and ^{90}Sr were relatively high in water from a few piezometers. The highest levels of ^{3}H ranged from 3.2–4.1 $\times 10^{6}$ pCi/L in samples from three piezometers located along Melton Branch downgradient from SWSA 5. Levels of ^{90}Sr ranging from 1485-2510 pCi/L were found in samples from three piezometers located in the vicinity of an old lake bed on WOC downgradient from SWSA 4. Elevated levels of ^{137}Cs were also found in water from wells in the two areas mentioned above as well as in water from two piezometers along Melton Branch downstream from the HRE and HFIR facilities and in an area of thick sediment deposits along WOC downgradient from the pits and trenches area. The highest ^{137}Cs and ^{60}Co levels, 324 and 62 pCi/L respectively, were found in water samples from a piezometer well downgradient from the pits and trenches area. The distribution of gross beta and ^{3}H activity in piezometers in the WOC floodplain is shown in Figures 42–43.

Since 1985, ORNL has installed at least 207 RCRA-quality groundwater monitoring wells. Eighteen of these wells, located in WAG 2, had been completed by the end of this reporting period. These wells were scheduled to be sampled in FY 1991. Parameters to be measured on samples collected from these wells include general water quality indices, (specific conductance, pH, and DO), radionuclides, (gross gamma, ^{3}H, ^{14}C, ^{60}Co, ^{90}Sr, ^{99}Tc, and ^{137}Cs), metals (ICP analysis), anions (NO^{-}_{3}, F^{-}, SO^{-2}_{4}, Cl^{-}, Br^{-}, and PO^{-3}_{4}), volatile and semivolatile organics (GCMS analysis), pesticides, and PCBs. Sampling was scheduled to be conducted during both high- and low-water table conditions. Numerous wells in upgradient WAGs will also be sampled for water quality parameters.

Water quality monitoring wells located in WAGs 1, 5, 6, and 7 are monitored by the ORNL ESP in accordance with EPA regulations. Data were collected semiannually for the reporting period and analyzed for a suite of general indicators and radionuclides at all sites, as well as for inorganics (metals, etc.) at WAGs 1, 5, and 7, and organics at WAGs 1 and 6. See Section 3.4 for a complete list of parameters analyzed at each site.

Rock core and geophysical logs from a 900-ft core hole drilled by Selfridge at WOD indicate fractured rock throughout the length of the core hole, but suggest that little groundwater flow occurs below 400 feet. Analyses of water samples collected at depths of 44 feet and 270 feet showed no radiological contamination. Subsequent packer-pressure tests were conducted in the core hole to estimate permeability values for different water-bearing zones. RAP reports on packer-pressure testing of the WOD core hole and 5 other core holes in the main ORNL plant area have been prepared (Golder Associates 1987).

3.3.4 Groundwater Levels

Beginning in 1986, G. K. Moore studied water level and hydraulic conductivity throughout the RAP piezometer well network. The objectives of the studies were: (1) to determine the configuration of the water table, directions of groundwater flow, and lateral and vertical hydraulic gradients; (2) to monitor short-term and seasonal water level changes resulting from variations in precipitation; (3) to monitor long-term water level trends in representative wells to detect effects of climate change or human activity; and (4) to

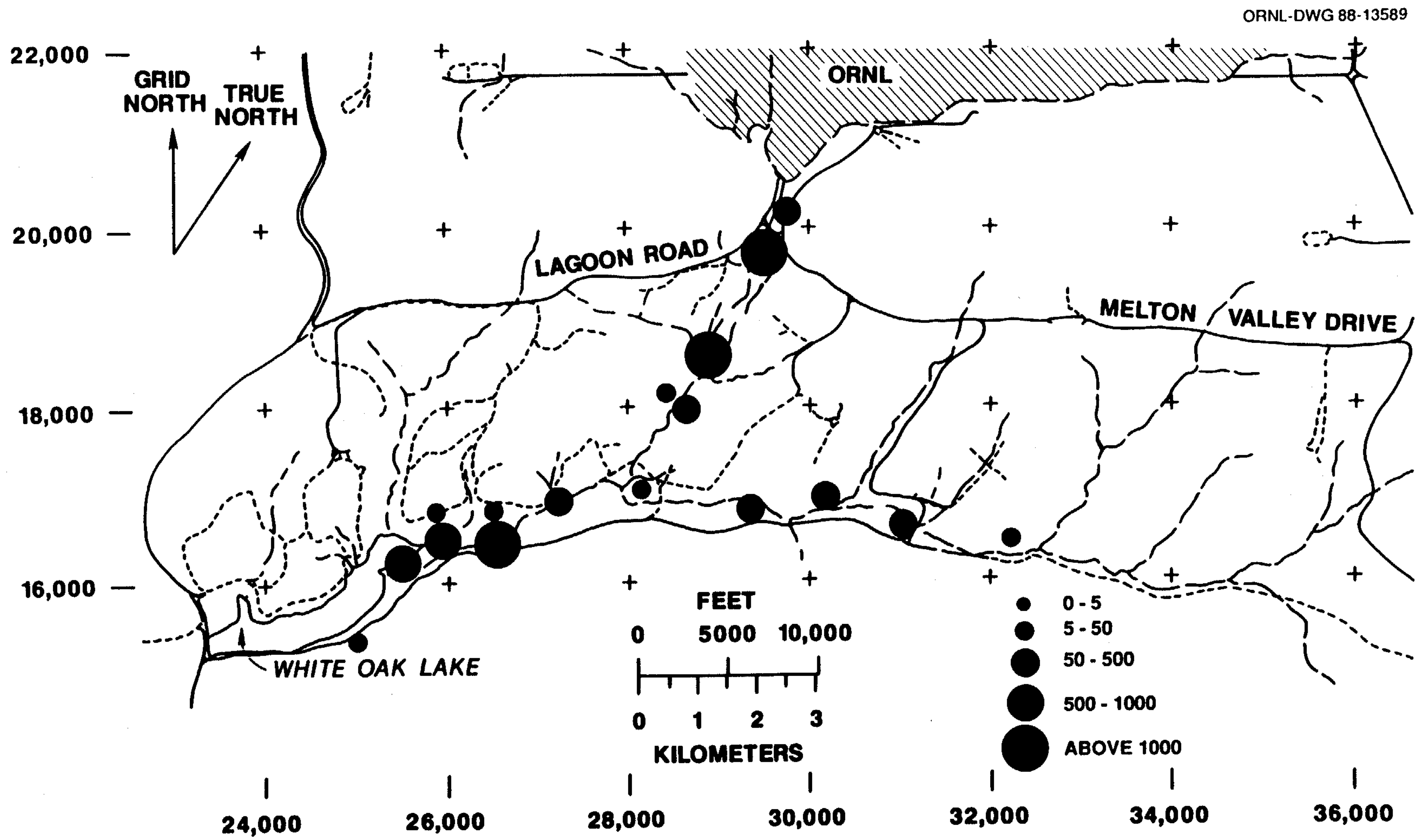

Fig. 42. Distribution of gross beta activity in piezometer wells located in the Whiteoak Creek floodplain. Units=pCi/L.

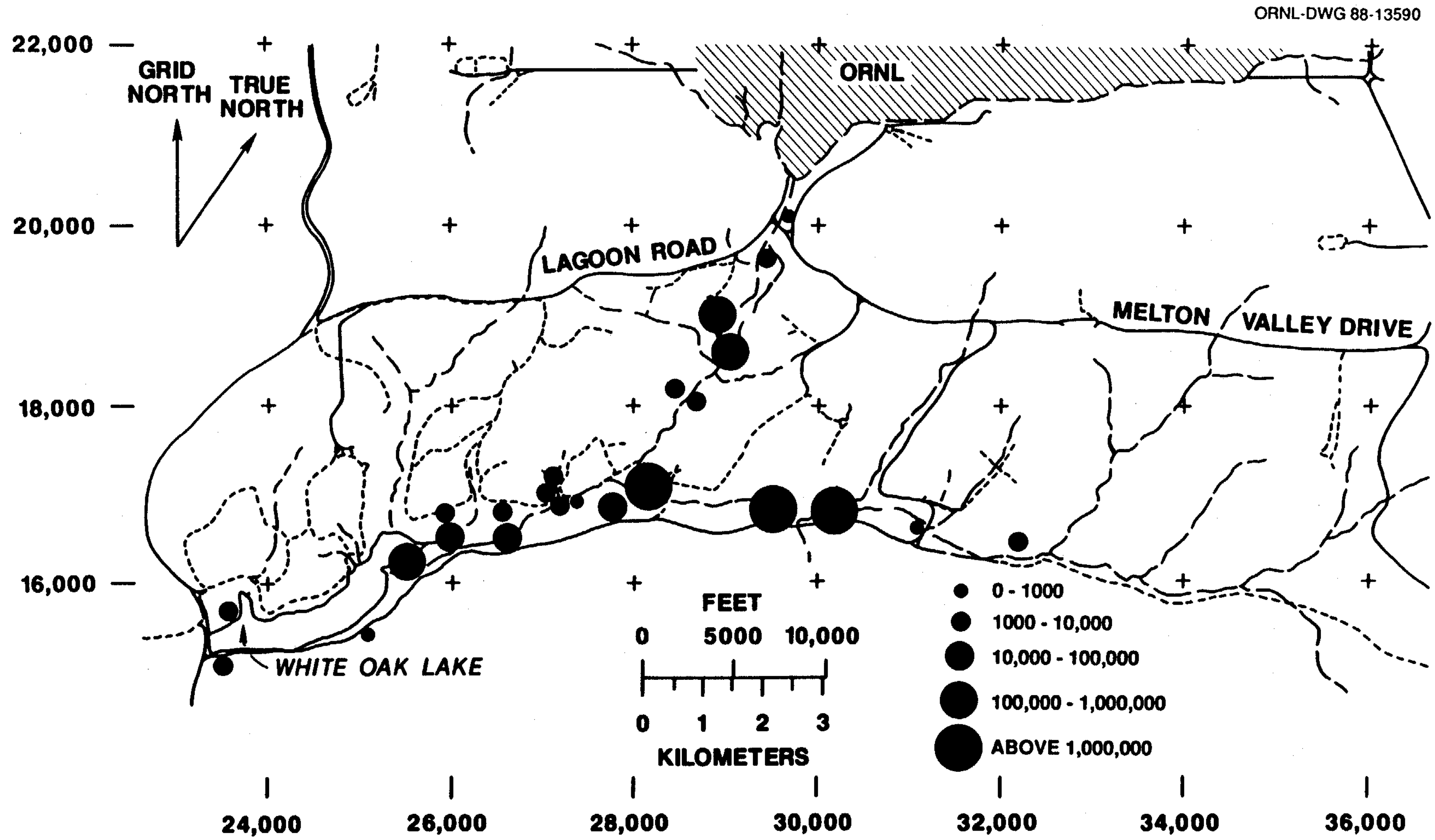

Fig. 43. Distribution of tritium in piezometer wells located in the Whiteoak floodplain. Units=pCi/L.

determine groundwater flow characteristics in the shallow subsurface materials by conducting hydraulic conductivity tests on a large number of piezometer wells.

The initial results of this study, including a graphical analysis of the data collected on geologic conditions, water level fluctuations, and aquifer characteristics, were interpreted by Moore and others (1991). Appendix D provides a summary of well and water level information for 126 wells in the Whiteoak Watershed (Fig. 44) as a reference to water table conditions in different locations in the ORNL area.

Figure 45 shows hydrographs for two wells in the headwaters region of Melton Branch. Well number 7-12 is in the proposed SWSA 7, and well number 1123 is located in the SWSA 7 Area. Although well 7-12 is missing 9 monthly observations and well 1123 is missing 11 monthly observations, these two wells represent the most complete and continuous coverage of water level data for groundwater wells in the WOC watershed for the period spanning the previous reporting period through the current Water Year (a total of 41 months from May 1987—September 1990). Fortunately, none of the missing data for well 1123 coincide with missing measurements at well 7-12. The hydrographs show similar long-term trends with respect to changes in precipitation; however, the magnitude of the responses varies dramatically due to differences in aquifer storage capacity and permeability, hydraulic gradients, and the nature of the groundwater flow paths in the vicinity of each well. Most efforts to collect continuous groundwater level data in the WOC system have been discontinued for various reasons or are sporadic at best.

Flow nets (Fig. 46-48) showing the configuration of the water table and flow lines in the ORNL area were prepared from water level measurements made at the time of the seasonal low in October 1986. The equipotential lines on the flow nets show the configuration of the water table. However, the streamlines show only the general direction and relative quantity of groundwater flow because local movement of groundwater is largely controlled by the sizes and orientations of fractures in the rock (Sledz and Huff 1981). Apparent hydraulic gradients calculated from the flow nets range from medians of 0.007 (along-valley), and 0.016 (cross-valley) in flat areas to 0.4 on steep hillsides.

A contour map of seasonal water level change in the ORNL plant area (WAG 1) from October 1986—March 1987 (Fig. 49) shows changes of less than 1 ft in several areas. These anomalous areas may represent artificial control of water levels by the drainage effects of storm sewers, leakage into or out of underground pipe, or the increased permeability of trench materials.

3.4 DATA AVAILABILITY

3.4.1 Environmental Sciences Division (ESD)

For several years, ESD's Watershed Hydrology Group has been collecting and processing discharge data at a number of stations in the WOC watershed and vicinity for modeling studies, independent research, and for remedial action activities. Discharge data are available in raw stage data format, hourly or daily discharge, and in hardcopy or computer formats.

ORNL-DWG 91M-13702

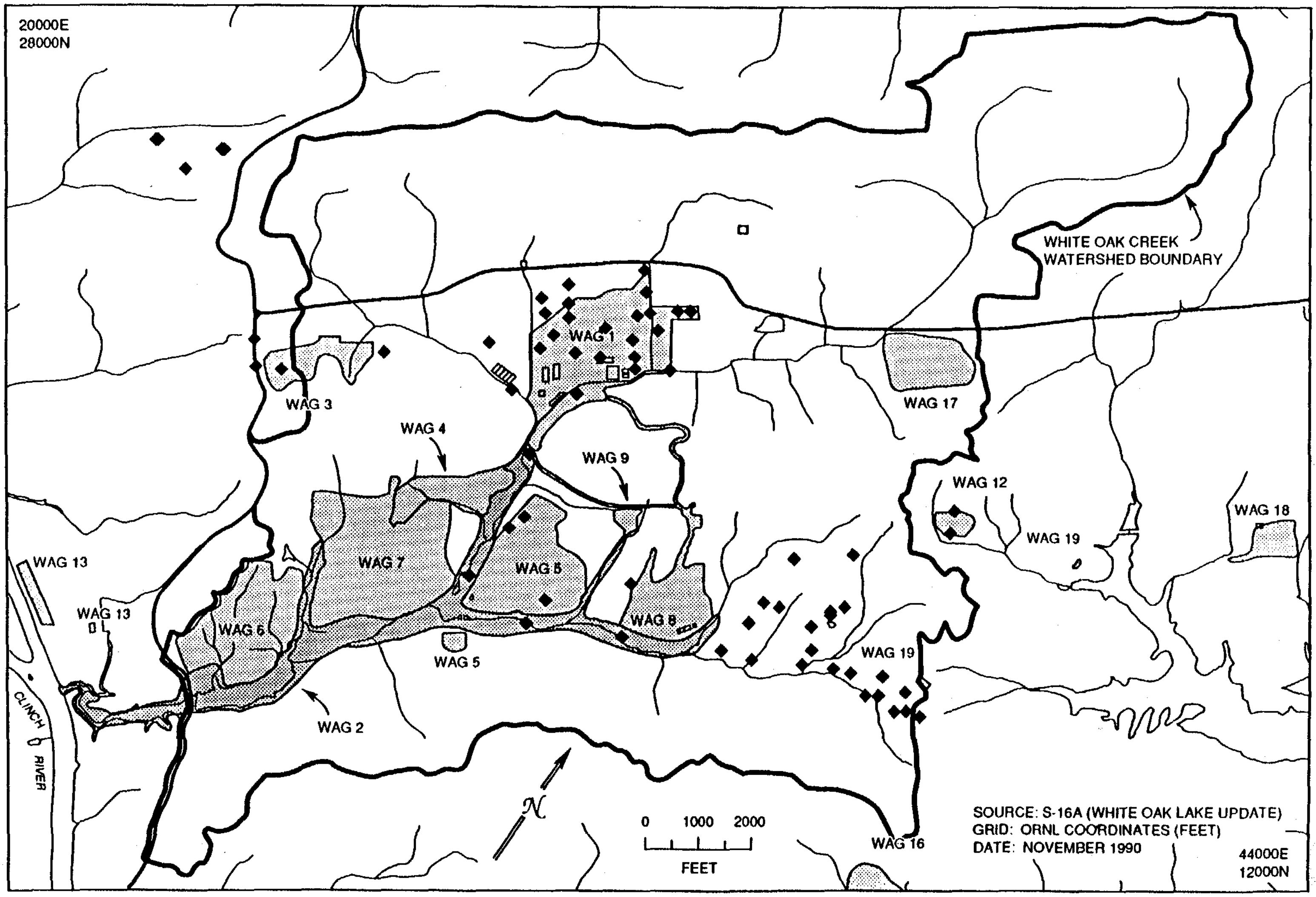

Fig. 44. Locations of WOC watershed groundwater wells that were sampled in Water Year 1990.

ORNL DWG 91-14915

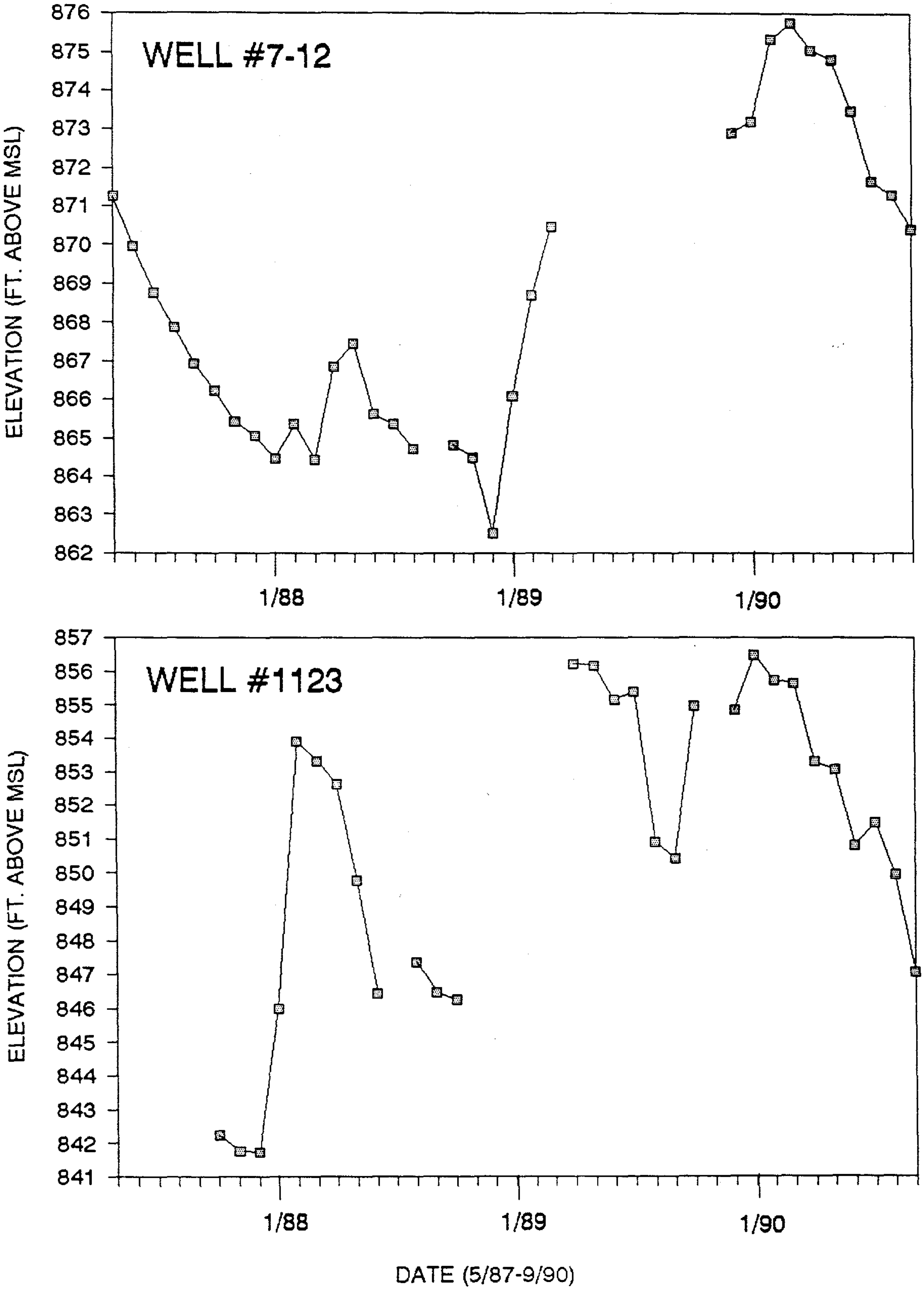

Fig. 45. Hydrographs of two wells in the headwaters region of Melton Branch.

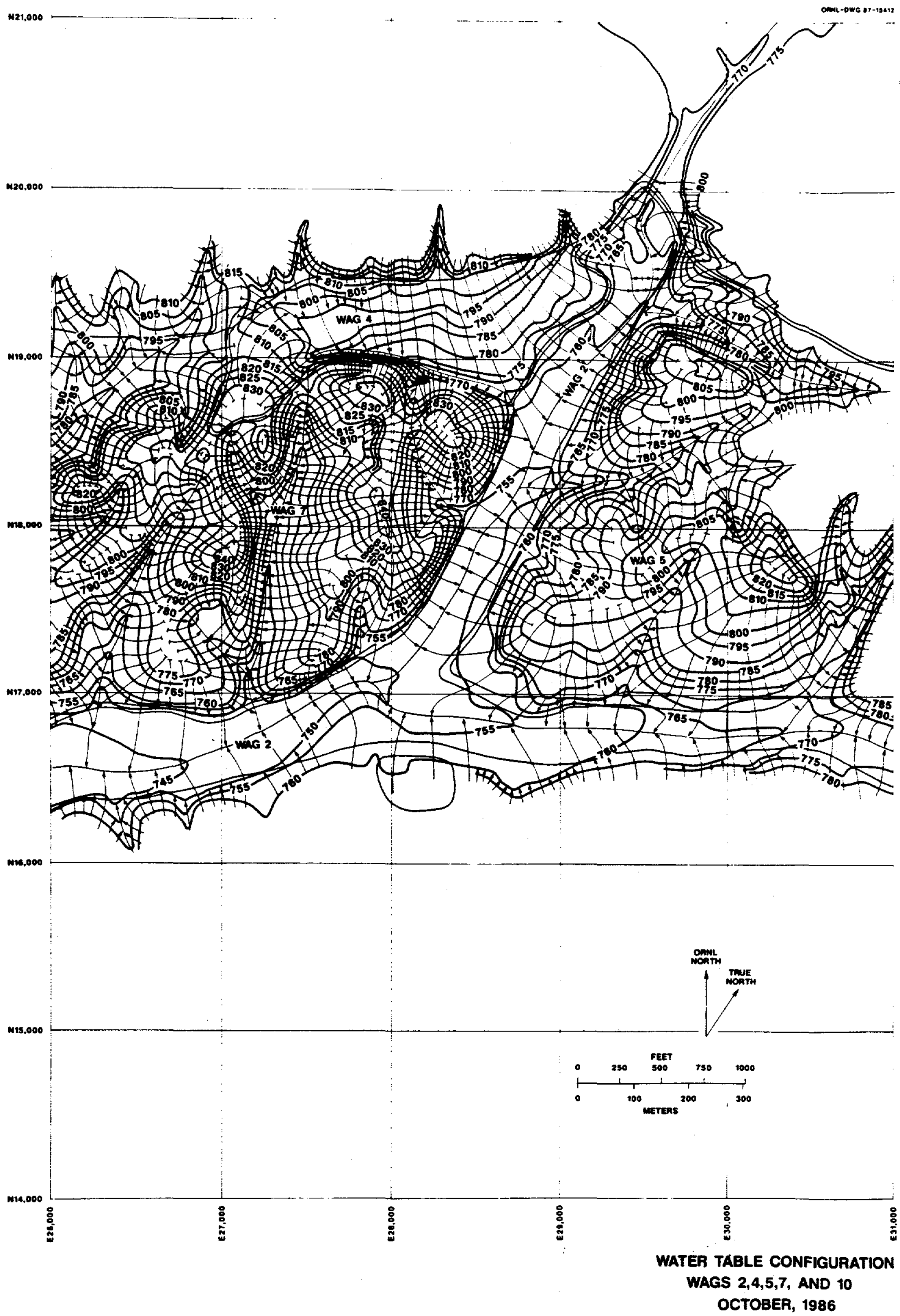

Fig. 46. Flow net showing the configuration of water table and streamlines for WAG 4, 5, 7 and part of WAG 2 in October 1986.

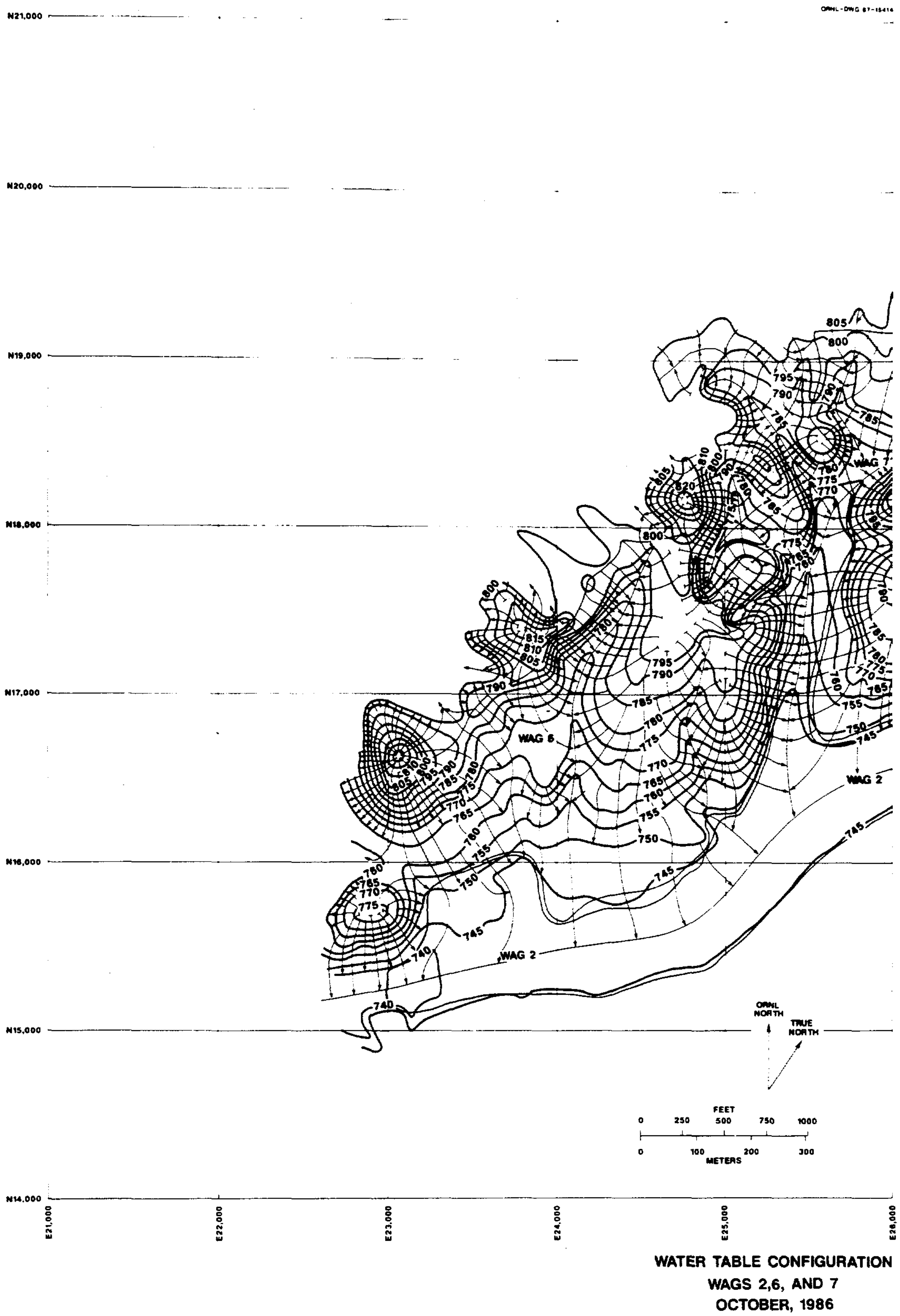

Fig. 47. Flow net showing configuration of water table and streamlines for WAG 6 and part of WAG 2 in October 1986.

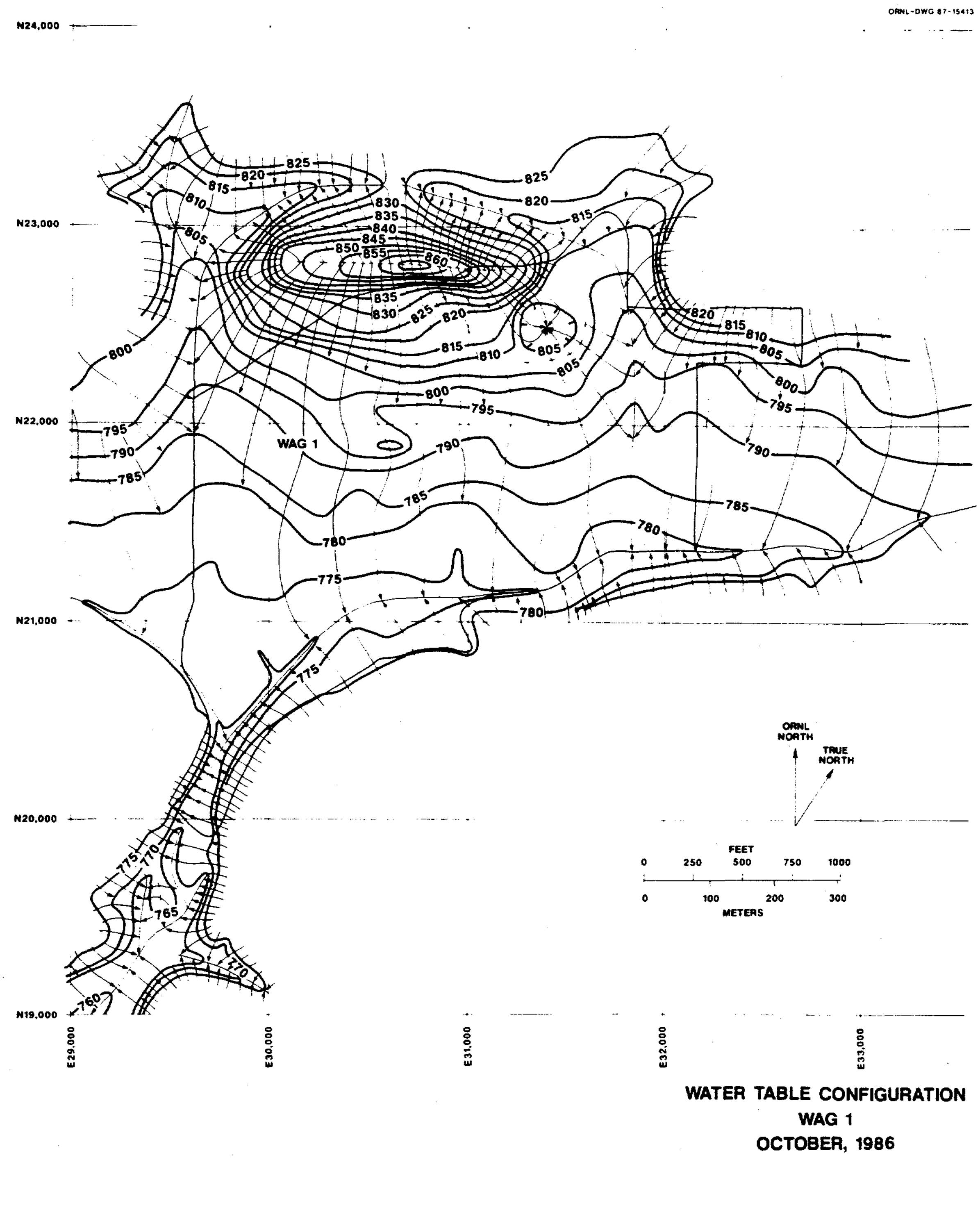

Fig. 48. Flow net showing the configuration for water table and streamlines for WAG 1 area in October 1986.

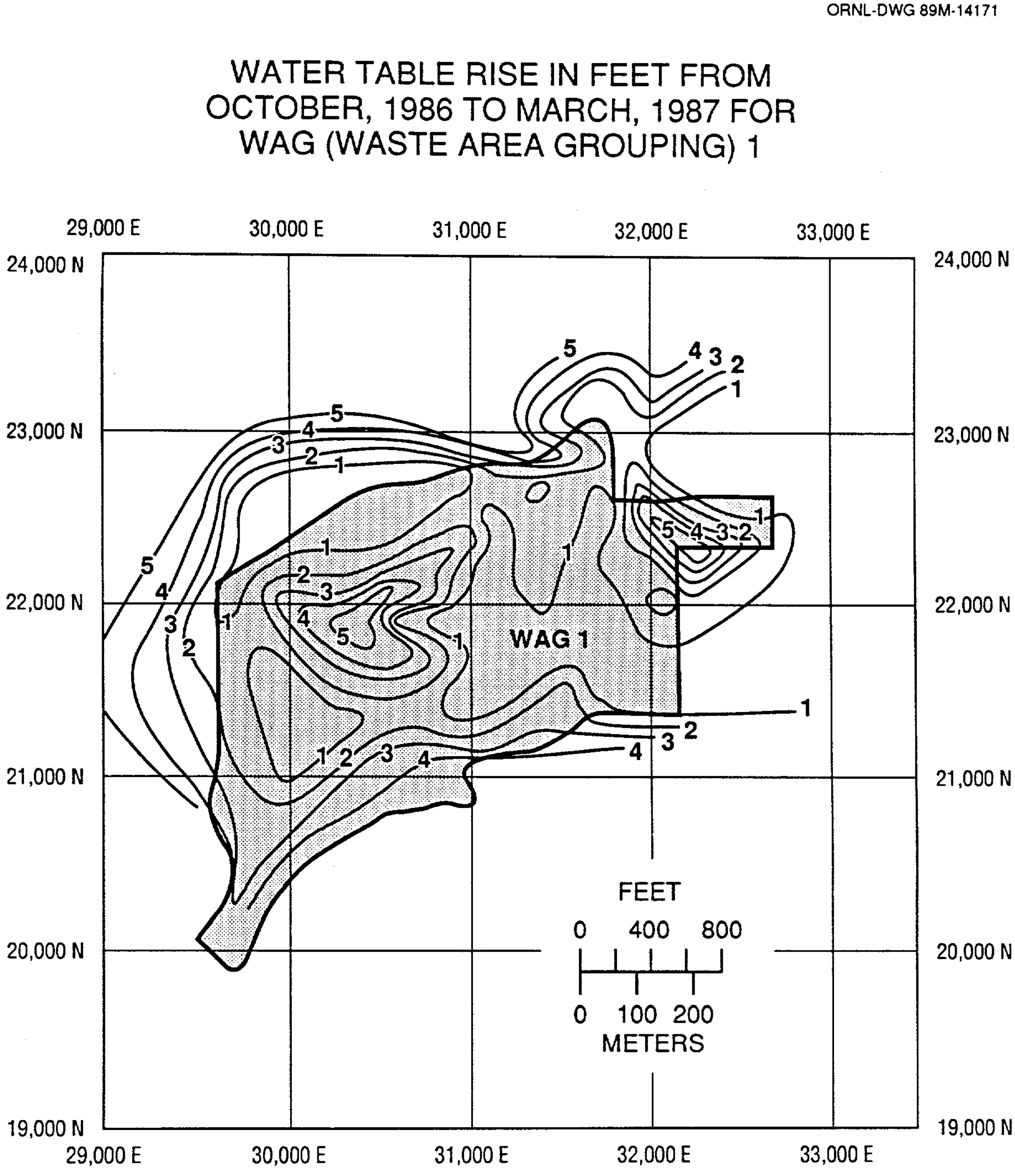

Fig. 49. Seasonal water table fluctuation in WAG 1 from October 1986 to April 1987.

The ESD surface water monitoring stations for which data are available are presented in this report. In addition, 15-min stage data are available at the mouth of WOC on the Clinch River for the period of this report.

Nine precipitation gages in the WOC watershed and vicinity are operated by ESD's Hydrology Group. Strip charts are collected weekly at each site and processed into monthly records of daily precipitation totals. Improved digitizing software may soon make available finer resolution (i.e., hourly data).

In addition to surface water discharge and precipitation data, ESD's Watershed Hydrology Group collects meteorological data. Wind speed and direction, temperature, pan evaporation, solar radiation, and humidity data are available from a number of sites. However, the period of record varies from station to station, and some records are discontinuous.

3.4.2 U. S. Department of the Interior, Geological Survey (USGS)

Surface water discharge and precipitation data are available from the USGS for a number of stations on the WOC watershed and the Oak Ridge Reservation. In addition, data on water quality, sediment, groundwater level, groundwater quality, and chemical quality of precipitation are available from the USGS for stations in the state of Tennessee and are published in annual *Water Data Reports* for the Water Year (USGS 1991).

All USGS surface water discharge data published in this report, and precipitation from a number of gages in the WOC watershed, are available by remote connection to the USGS computer system based in Nashville, TN. Data are available in unit values (5 minute to hourly) at selected stations and daily values for all stations. Rating tables, and the data collected for the development of them, are available for most surface water monitoring stations in the system. In addition, near real-time data (discharge, precipitation, etc.) are available from a number of stations connected to the USGS computer system by satellite telemetry via data collection platforms (DCPs). The 7500 Bridge (GS3) station is the only such station in the WOC watershed on a DCP, thereby providing near real-time data (15-minute delay) under high-flow conditions. The 7500 Bridge station also has a precipitation gage connected to the DCP to provide near real-time rainfall data at 15-min intervals.

The ESD Watershed Hydrology Group recently requested, from the USGS subdistrict office in Knoxville, TN, unit data for all area (WOC vicinity) surface water monitoring stations . These data have been requested for all stations since approximately 1987, to be delivered in ASCII format on floppy discs. Most of the data from stations in the WOC watershed and vicinity are not available in unit values on the USGS computer system. It is important that these data be made accessible to researchers for modeling purposes.

3.4.3 Environmental Surveillance and Protection (ESP) Section

The two primary monitoring activities of the ESP are effluent monitoring and environmental surveillance. Those activities that bear directly on the WOC watershed are summarized in Table 11 (Sect. 3.2.2). Also, Figures 50-54 identify the sampling locations of

ORNL-DWG 89M-6365R5

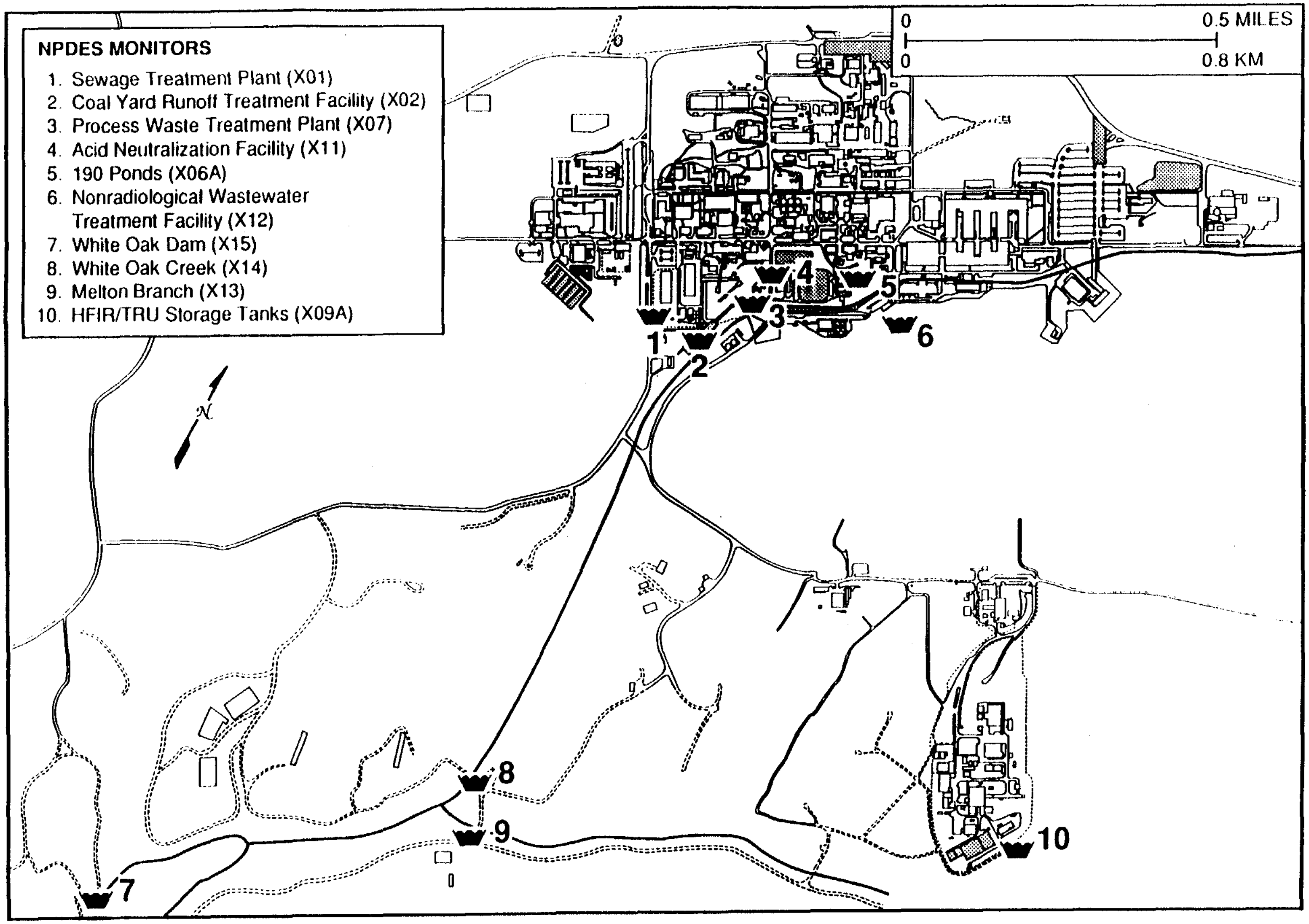

Fig. 50. ORNL NPDES and radioactivity sampling locations.

ORNL DWG 86 1202684

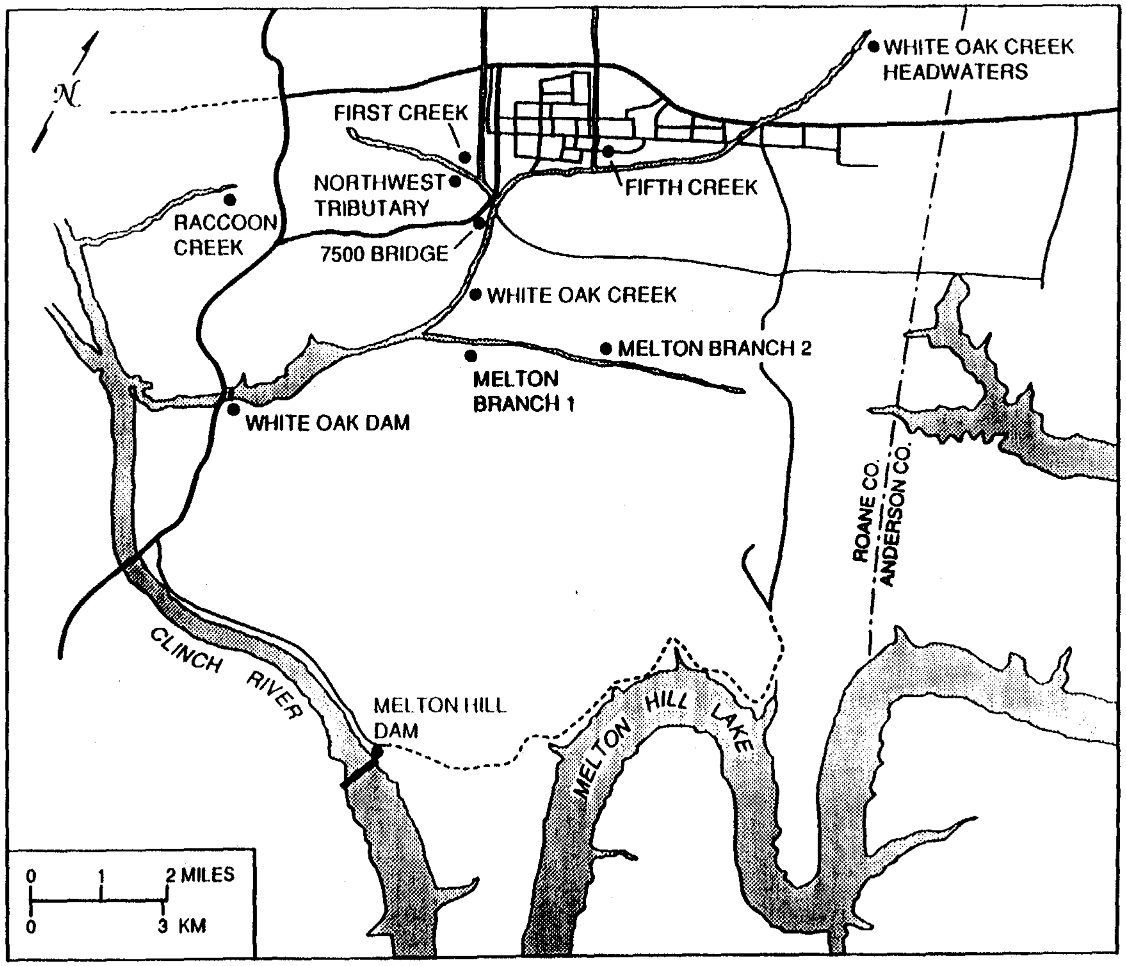

Fig. 51. ORNL ESP surface water and reference sampling locations.

ORNL-DWG 89M 6126R2

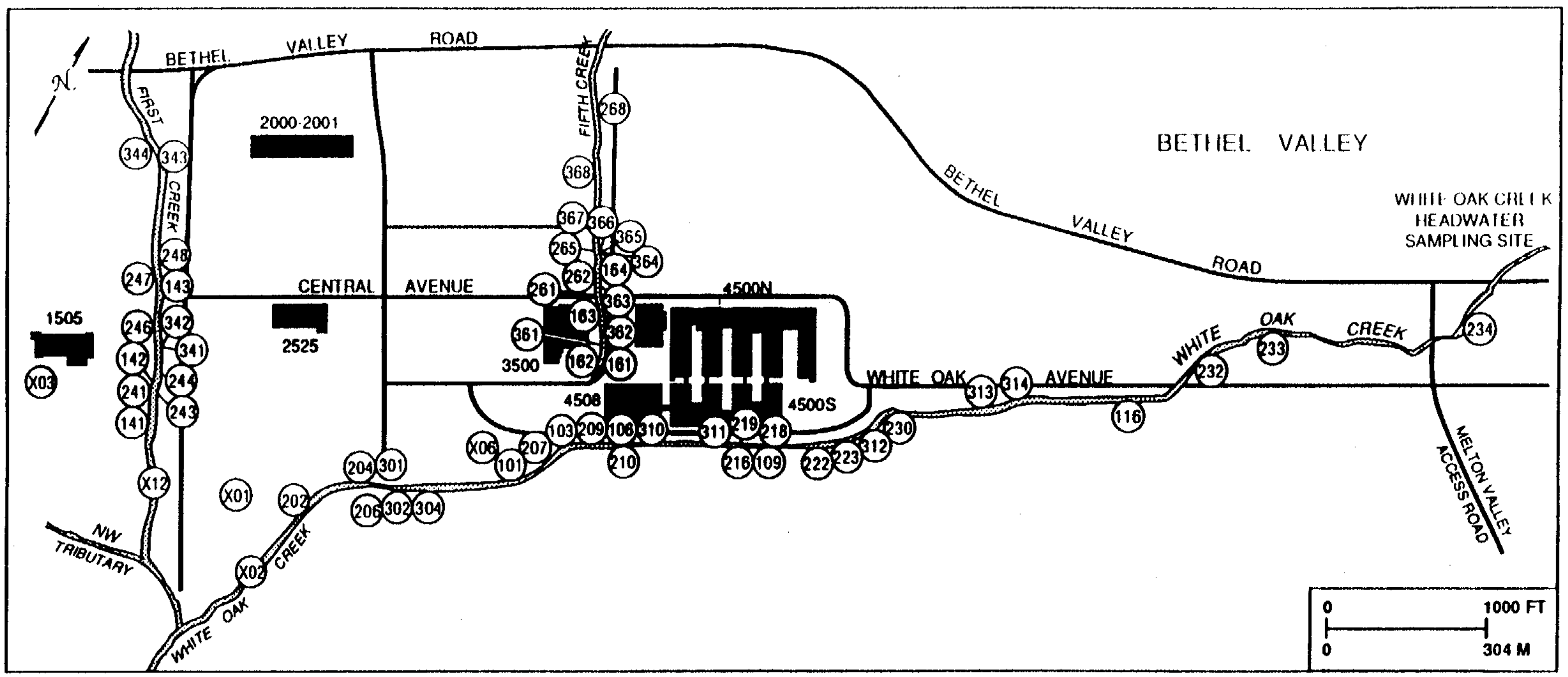

Fig. 52. Map of ESP water sampling locations for mercury in the ORNL area.

ORNL DWG 89M 6129R3

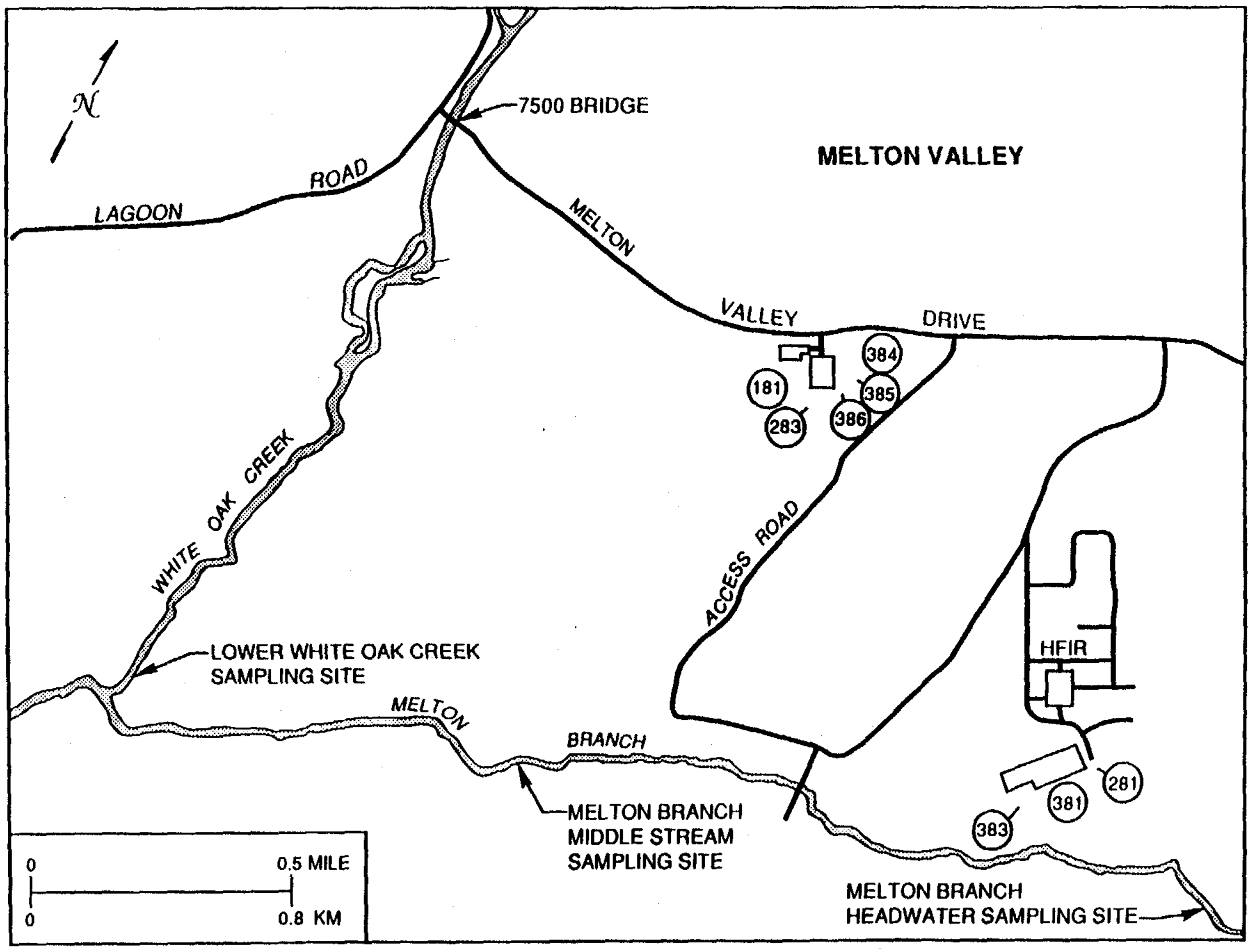

Fig. 53. Map of ESP water sampling stations for mercury in the ORNL Melton Valley complex.

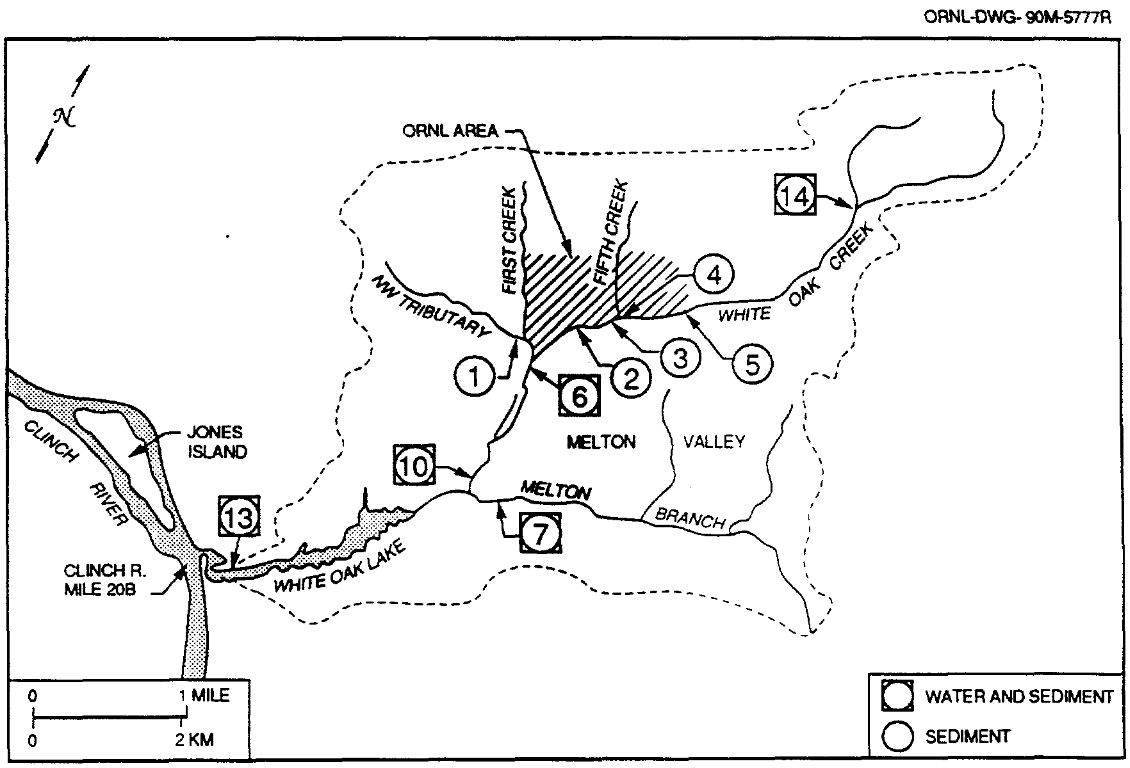

Fig. 54. ESP Sample locations for PCB and TOC (sediment only) analyses in the ORNL area.

these data. This information reflects the general activities of the ESP for the 1990 Water Year.

In addition, hourly discharge data are available from the ambient water monitoring stations on WOC, MB, and WOD. These data are available in near real-time from the ESP Data Acquisition System (DAS) located on ESP's dedicated VAX 11/750 digital computer system.

3.4.4 Remedial Action Program Data and Information Management System (RAP/DIMS)

Many ORNL programs collect and report hydrologic data for a number of reasons. The ORNL ERP data base (RAP/DIMS will be part of the Consolidated Data Base in the near future) is the repository of all data and information generated by activities related to the ERP and GWPP. The Bibliographic Data Base is a repository for all published reports produced for the program and for any other pertinent publications. The Records Control Data Base indexes unpublished information (e.g., project plans and field notebooks) generated by the program. The Numeric Data Base is a central repository for technical data generated in the ERP and GWPP and data from other studies of interest.

The ORNL RAP/DIMS data base and its contents have been documented in several annual reports (Voorhees et al. 1988, Voorhees et al. 1989, Hook et al. 1990). For information on the RAP/DIMS data base and availability of information from the data base, contact:

Larry D. Voorhees
Manager, RAP Data and Information Management System
Building 1505, MS 6035
Oak Ridge National Laboratory
P. O. Box 2008
Oak Ridge, Tennessee 37831-6035

Telephone: (615) 574-7309 or FTS: 624-7309
ORNL E-mail ID: LDV

4. DATA PROCESSING

4.1 Stream Discharge Data

Stream stage data at flumes and weirs are measured and recorded by one of two monitoring systems. Some sites are equipped with electronic data loggers and submergible pressure transducers that record data on electronic data storage packs, and some are equipped with mechanical float and pulley recorders that record data by punching paper tapes. After translating paper punch tapes and reading data storage packs, the data processing for both methods is the same.

Computer files of raw unaltered stage data are archived. The data is then reduced by removing redundancies. This is done by producing files of breakpoint data with a program called EZ-BRK2 written for ESD by Environmental Consulting Engineers (ECE). At this stage of processing, the stage data is corrected for recorder drift according to visual inspections of staff gage readings. The stage data is then processed to produce reports of discharge data with the REPORTER program, also developed by ECE. Hydrographs of the data are produced and compared with field notes to find inaccuracies caused by debris clogging the flow-measuring structure, faulty equipment, submergence, etc. Data are corrected when possible; and if the data cannot be corrected, they are removed from the record. Estimates, by hydrograph comparison and comparison of precipitation records, are then made using data from stations in the immediate vicinity. For the MS4 site on Melton Branch, all high–flow data is adjusted to account for submergence effects.

4.2 Precipitation Data

Rain gage charts are collected weekly from nine rain gage sites equipped with a Belfort Universal Recording Rain Gage. These charts are digitized to produce raw breakpoint data using a commercial digitizing program, EASYDIG; and RAINCHT2, a program developed by Roger Clapp of ESD. The breakpoint data are then converted into monthly reports of daily rainfall totals using P-REPRT2, also developed by Roger Clapp. The P-REPRT2 program also has the ability to produce reports in the Terrestrial Ecology and Hydrology Model (TEHM) format.

Rainfall data for a site is validated by comparing the P-RERPT2–generated, daily rainfall totals for a site to the site's original rain gage charts. Comparison of data from site to site is also done as an additional check. Original rain gage charts are archived and hardcopies of monthly reports of daily totals are retained. Computer files of the monthly reports and the breakpoint data used to create the reports are maintained by the ESD Watershed Hydrology Group.

4.3 Software Systems

In addition to the software packages described in the previous section that is used to process the streamflow and meteorological data collected by the ESD Watershed Hydrology Group, the data may also be processed into LOTUS 1-2-3 or Statisical Analysis System (SAS) files. The data, for the most part, are processed on a PC system. Data are stored on Bernoulli disks, floppy, and hard disks. Copies of the files are maintained with each notebook containing reports (listings) of the data. Copies are maintained in separate locations to protect the disks from possible damage. Descriptions of the data backup and security procedures used in the ESD Watershed Hydrology Group are contained in the "Surface Water Flow and Quality Measuring Sites and Surface Water Data Processing and Interpretation" Plan that is currently under review.

5. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

Quality assurance for data collection and data processing in the Environmental Sciences Division's Hydrologic Data Center is governed by a QA plan developed to comply with the Environmental Sciences Division's "Quality Assurance Manual." In addition, a QA/QC plan for the WAG 2 RI Plan (1990) and the ERP QA/QC Plan (in review) also apply to data collected in the surface water monitoring project. Quality control is achieved through several steps. Procedures and guidelines have been developed covering data collection and data processing from the point of data origination in the field to final report preparation. Attempts at data verification are made and are mentioned in the data processing section of this report.

Following the lead of the Information Integration and Analysis Group, Office of Environmental and Health Protection, Oak Ridge National Laboratory, the ESD Watershed Hydrology Group is initiating a data quality hierarchy along the line of that used for field sampling and laboratory analyses data quality objectives. This hierarchy is summarized in Table 15.

Table 15. Data product hierarchy for the ESD Watershed Hydrology Group surface water monitoring program

LEVEL	DESCRIPTION
0	Unmodified data printout and/or electronic file that includes all variables in the order collected at monitoring stations.
1	Data printout and/or electronic file including only the variables of interest to the user, sorted to the user's specifications, including a description of variable formats and locations for ASCII files. The data are rounded to the appropriate number of significant digits.
2	Data summaries such as maximum, minimum, and mean tables, frequency distributions, data plots, etc. The report quality consists of unaltered REPORTER, LOTUS 1-2-3, or Statistical Analysis System (SAS) procedures output as formatted by the default output option. These summaries can be in hard copy and/or electronic format.
3	Presentations of spatial or temporal relationships among the data or comparisons to regulatory criteria. Regulatory criteria is specified by the user. Report quality consists of data presentations with header and footer information requested by the user. Information can be provided as electronic files or laser printer hard copy.
4	Graphic or tabular data presentation suitable for publication or presentation.

Adapted from tables in memo dated May 31, 1991 from Mark F. Tardiff, Group Leader, Information Integration and Analysis Group, Office of Environment and Health Protection, Oak Ridge National Laboratory.

6. SUMMARY AND RECOMMENDATIONS

The collection and reporting of quality hydrologic data are essential to fulfilling the goals of the ER monitoring program to support a mass balance approach to determine sources and sinks of contaminants in the WOC system. This includes defining and quantifying the input of wastes from ORNL WAGs.

Surface water is the primary pathway for the release of contaminants from the WOC system to off-site areas. Therefore, it is of vital importance for the objectives of the ER monitoring program (to quantify mass fluxes of contaminants from ORNL waste sources) that surface water monitoring network be comprehensively evaluated and, where necessary, upgraded. In addition, it is essential that surface water monitoring stations be upgraded if any interim measures are to be effectively evaluated. Some progress has been made through initial efforts; however, much remains to be done.

A number of issues concerning sediment deposition continue to plague efforts to collect data on surface water discharge in the WOC watershed. Sediments, which are contaminated at most sites in the WOC flow system, have filled the stilling pools upstream from weirs and are adversely affecting the accuracy of discharge measurements in several ways:

1. Increased velocities of approach alter the stage-discharge relationship;

2. Stilling wells become plugged, causing erroneous stage data; and

3. Accumulated sediments foster the growth of aquatic vegetation which obstructs weir plates and clogs sample intake lines.

Regulatory guidance on both manual methods and engineered structures (e.g., installation of plugs in control structures for passing sediment downstream) is needed on issues pertaining to sediment removal, disposal, and mitigation issues. Some progress has been made here through the process of NEPA documentation, however, the process is painstakingly slow. In addition, a study by EBASCO, Inc. will determine alternative methods and estimates for removing sediments. This effort is being coordinated with ESD hydrologists, ESP, ORNL Engineering, and Project Engineering staff. However, a funding commitment is needed before sediment can be adequately removed from major monitoring stations.

Discharge data collected from station MS4 on Melton Branch has been shown to be grossly in error during high-flow conditions due to submergence of the broad-crested weir. A number of measures have been employed or proposed to improve data accuracy, but they have not actually corrected the problem. An extended rating, which was developed theoretically using the upstream control above its intended range, has been used by ESD to improve the accuracy of high-flow data. This extended rating will be field verified and adjusted accordingly by the USGS during FYs 1992 and 1993. However, the monitoring station should be redesigned to establish a permanent hydraulic control at the upstream location (current low-flow location). An alternative is to remove a section of the concrete trunk line downstream crossing the channel and improve channel capacity enough to keep the upstream control from submerging.

The trunk line acts as a limiting tailwater control that establishes a maximum degree of improvement to existing submergence conditions at the upstream monitoring station (MS4). This could be achieved without removing the trunk line. Additional modeling studies would be required to determine the magnitude of possible channel improvements on correcting submergence problems if the trunk line were removed. To ensure that MS4 would not be adversely affected by WOC, design flow conditions should be used in model studies to consider the effects of backwater from WOC.

High-quality discharge data, precipitation data, meteorological data, and continuous water level measurements in wells at multiple sites in the WOC watershed are needed to determine a water budget for the WOC system. Better information for water budgets can help identify areas of contaminant input based on differences in mass fluxes. Steps are being taken to improve the quality of discharge and meteorological data, and adequate coverage of precipitation data in the vicinity of the WOC watershed already exists.

However, the collection of water level measurements in wells has decreased in the last several years. Also, most wells are currently measured manually on a monthly basis; this reduces some of the resolution that would be detected with weekly or continuous measurements. Continuous recording devices, either mechanical or electronic, are relatively simple to install, operate, and maintain. Field verification consists of the same method currently employed to obtain the primary water level measurements. It is strongly recommended that the collection of continuous water level measurements in wells in the WOC watershed be expanded to improve water budget summary calculations.

The ERP and compliance groups must comprehensively coordinate surface water monitoring activities in order to effectively meet the monitoring objectives of both programs. This coordination should be developed under the direction and support of the upper levels of administration within ORNL. Only in this way can surface water monitoring activities be carried out effectively, without redundancy and with a clear delineation of responsibilities between the two groups. In the past, there have been minor problems, primarily related to poor communication and the perception of a one-way flow of information, due to this lack of coordination. Surface water monitoring efforts should also be coordinated with the groundwater monitoring program (GWPP) to establish unified management of hydrologic monitoring at ORNL.

The ESD Watershed Hydrology Group will help ESP resolve problems with discharge measurement, primarily at MS4 (described above), and with the effects of poor data on compliance monitoring (e.g., overestimation of mass fluxes of ^3H at MS4 due to overestimation of discharge caused by submergence). Adjusted data will be used to calculate the mass of contaminants for environmental surveillance reporting. In addition, new monitoring systems and procedures for the design and upgrade of surface water monitoring stations are being developed with the assistance of I&C Division and ORNL Engineering.

Future hydrologic data summaries with broadened objectives will be produced in conjunction with the Environmental Restoration Monitoring and Assessment (ERMA) program. Beginning in FY 1992, the annual data report will serve as one part of a comprehensive monitoring plan that will identify spatial and temporal trends, interpret those trends, and more extensively assess the releases from contaminated WAGs.

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APPENDIX A

Daily Precipitation Totals for Stations in Whiteoak Creek Watershed

Table A.1. Daily precipitation totals for Water Year 1990 at the 7500 Bridge station
Units=mm

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	9.4	0.0	0.0	0.0	0.0	2.0	0.0	52.6	0.0	42.42	0.0	0.0
2	0.0	0.0	0.0	0.0	1.5	16.5	0.0	0.0	0.0	0.0	0.3	0.0
3	0.0	0.0	0.0	0.3	52.1	0.8	0.0	21.1	3.56	0.0	0.0	0.0
4	0.0	0.0	0.0	12.7	6.6	0.0	0.0	17.0	0.0	0.0	14.5	0.0
5	0.0	0.0	0.0	4.6	0.0	0.0	0.0	0.3	0.0	0.0	31.5	0.0
6	0.0	22.4	0.0	3.8	0.8	0.0	15.24	1.3	0.0	0.0	0.8	0.0
7	0.0	15.2	2.8	4.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	11.2	11.7	12.5	0.0	3.6	0.0	0.0	0.0	0.0	8.1	0.0
9	0.0	1.3	0.3	0.0	19.8	3.1	0.0	16.3	16.26	0.0	14.0	0.0
10	0.0	0.0	0.0	0.3	19.1	7.1	6.35	4.1	7.11	0.0	0.0	0.0
11	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	21.59	0.3	0.0
12	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	35.31	0.0	4.3
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.38	0.0	2.3
14	0.0	8.1	0.0	0.0	0.0	0.0	4.57	0.0	2.79	14.99	14.2	13.7
15	0.0	39.4	0.8	0.0	11.7	2.8	0.0	0.0	0.0	0.0	0.0	0.3
16	19.1	0.0	0.0	0.0	33.3	47.2	0.0	0.0	0.0	0.0	0.0	0.0
17	10.7	0.0	0.0	0.5	0.0	15.8	3.81	21.1	0.0	0.0	7.6	0.0
18	9.4	0.0	0.0	19.3	5.8	0.0	0.0	0.0	0.51	0.0	0.3	0.0
19	0.3	0.0	5.8	0.0	5.3	3.1	0.0	0.0	0.0	2.29	0.0	0.0

Table A.1 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.0	0.0	0.0	28.7	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0.1
21	0.0	0.0	0.0	0.3	0.0	0.0	10.16	1.0	1.02	21.34	8.1	0.3
22	0.0	19.6	0.0	0.0	8.4	0.0	0.25	0.3	7.11	5.84	6.6	0.8
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.3	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.3	0.5	0.0	0.0	0.0	0.0	8.6	0.0	0.0	0.0	0.0
27	0.0	1.8	0.0	0.0	0.0	0.0	0.0	19.8	0.0	0.0	0.0	0.0
28	0.0	13.2	0.0	0.0	0.0	0.0	14.99	19.1	0.0	0.0	0.0	0.0
29	0.0	0.0	1.5	33.0		3.6	0.25	0.0	0.25	0.0	13.0	0.0
30	0.0	0.0	13.2	0.0		2.8	0.0	0.0	0.0	0.0	0.0	0.5
31	4.6		28.2	0.0		0.3		0.0		0.0	0.0	

Table A.2 Daily precipitation totals for Water Year 1990 at the ETF station
Units=mm

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	8.6	0.0	0.0	0.0	0.0	3.3	0.0	57.2	0.0	28.7	0.0	0.0
2	0.0	0.0	0.0	0.0	2.0	18.8	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.3	61.2	1.0	0.0	27.7	4.8	0.0	0.0	0.0
4	0.0	0.0	0.0	12.2	6.4	0.0	0.0	12.5	0.0	0.0	19.8	0.0
5	0.0	0.0	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	25.9	0.0
6	0.0	24.3	0.0	4.3	1.3	0.0	9.4	1.5	0.0	0.0	3.1	0.0
7	0.0	16.3	1.8	4.6	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	14.2	13.2	13.2	0.0	6.1	0.0	0.0	0.0	0.0	11.2	0.0
9	0.0	1.5	0.8	0.3	23.4	3.1	0.0	18.3	33.3	0.0	17.5	0.0
10	0.0	0.0	0.0	0.0	20.1	8.4	7.1	4.3	11.2	0.0	0.0	0.0
11	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	25.7	0.0	0.0
12	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	5.8
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.9	0.8	2.3
14	0.0	7.4	0.0	0.0	0.0	0.0	5.8	0.0	8.1	17.0	17.5	1.8
15	0.0	38.1	0.8	0.0	21.3	3.1	0.0	0.3	0.0	0.0	0.0	22.4
16	20.3	0.0	0.0	0.0	36.6	53.6	0.0	0.0	0.0	0.0	0.0	0.0
17	20.6	0.0	0.0	0.5	0.0	16.0	5.8	21.3	0.0	0.0	10.9	0.0
18	9.4	0.0	0.0	20.3	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.6	0.0	6.5	0.0	5.3	3.6	0.0	0.0	0.0	4.6	0.8	1.3

Table A.2 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.0	0.0	0.0	31.2	0.0	0.0	0.3	8.4	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	11.2	0.8	0.0	28.5	5.3	7.4
22	0.0	21.6	0.0	0.0	10.4	0.0	0.0	0.0	7.4	3.6	8.4	0.8
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	1.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.5	0.3	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0
27	0.0	2.0	0.3	0.0	0.0	0.0	0.0	15.0	0.0	0.0	0.0	0.0
28	0.0	17.5	0.0	0.0	0.0	0.0	20.8	21.3	0.0	0.0	0.0	0.0
29	0.0	0.0	1.3	35.3		4.1	0.0	0.0	0.0	0.0	22.1	0.0
30	0.0	0.0	14.7	0.0		3.6	0.0	0.0	0.0	0.0	0.0	1.0
31	5.3		29.7	0.0		0.8		0.0		0.0	0.0	

Table A.2 (continued)

Table A.3. Daily precipitation totals for Water Year 1990 at the First Creek station
Units=mm

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	11.2	0.0	0.0	0.0	0.0	2.3	0.0	52.6	0.0	54.1	0.0	0.0
2	0.5	0.0	0.0	0.0	1.8	18.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.3	60.2	0.8	0.0	25.4	4.1	0.0	0.0	0.0
4	0.0	0.0	0.0	13.0	5.1	0.0	0.0	18.3	0.0	0.0	17.5	0.0
5	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	37.9	0.0
6	0.0	23.6	0.0	3.6	2.5	0.0	12.2	2.0	0.0	0.0	1.3	0.0
7	0.0	15.0	3.5	6.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	14.6	10.9	11.7	0.0	5.1	0.0	0.0	0.0	0.0	9.4	0.0
9	0.0	0.3	0.3	0.0	35.1	2.0	0.0	17.8	19.8	0.0	25.4	0.0
10	0.0	0.0	0.0	0.3	10.4	8.4	7.6	3.3	6.6	0.0	0.0	0.0
11	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	26.2	0.0	0.0
12	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	41.2	0.0	4.6
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.6	0.0	2.5
14	0.0	7.9	0.0	0.0	0.0	0.0	5.8	0.0	2.8	16.8	20.8	17.0
15	0.0	43.2	0.8	0.0	17.5	2.5	0.0	0.0	0.0	0.0	0.0	0.8
16	21.6	0.0	0.0	0.0	34.5	53.3	0.0	0.0	0.0	0.0	0.0	0.0
17	9.8	0.0	0.0	0.5	0.0	15.0	6.6	22.1	0.0	0.0	9.7	0.0

Table A.3 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
18	10.2	0.0	0.0	20.1	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.6	0.0	7.1	0.0	5.6	4.8	0.0	0.0	0.0	2.8	0.0	2.5
20	0.0	0.0	0.0	30.0	0.0	0.0	0.0	7.4	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	13.7	0.8	0.0	35.1	12.2	7.1
22	0.0	21.3	0.0	0.0	10.2	0.0	0.0	0.0	9.4	6.4	11.4	1.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	10.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.6	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.5	0.0	0.0	0.0	0.0	0.0	8.9	0.0	0.0	0.0	0.0
27	0.0	1.5	0.4	0.0	0.0	0.0	0.0	20.6	0.0	0.0	0.0	0.0
28	0.0	16.3	0.0	0.0	0.0	0.0	17.5	19.8	0.0	0.0	0.0	0.0
29	0.0	0.0	2.5	34.8		3.8	0.0	0.0	0.0	0.0	19.8	0.0
30	0.0	0.0	13.2	0.0		3.8	0.0	0.0	0.0	0.0	0.0	0.3
31	5.7		28.0	0.0		0.0		0.0		0.0	0.0	

Table A.4. Daily precipitation totals for Water Year 1990 at the SW7 station
Units=mm

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	9.4	0.0	0.0	0.0	0.0	2.5	0.0	47.8	0.0	45.2	0.0	0.0
2	0.0	0.0	0.0	0.0	1.8	17.8	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.5	56.6	1.5	0.0	25.7	4.3	0.0	0.0	0.0
4	0.0	0.0	0.0	12.2	6.9	0.0	0.0	15.2	0.0	0.0	14.7	0.0
5	0.0	0.0	0.0	4.1	0.0	0.0	0.0	3.6	0.0	0.0	26.9	0.0
6	0.0	22.3	0.0	3.8	0.8	0.0	17.5	1.0	0.0	0.0	2.0	0.0
7	0.0	15.3	2.8	5.1	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	10.2	10.9	12.2	0.0	5.1	0.0	0.0	0.0	0.0	9.4	0.0
9	0.0	0.6	0.6	0.0	23.6	2.5	0.0	16.5	20.1	0.0	33.0	0.0
10	0.0	0.0	0.0	0.0	17.8	10.7	7.4	4.1	4.8	0.0	0.0	0.0
11	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	23.1	0.0	0.0
12	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	42.4	0.0	4.8
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.9	0.5	2.0
14	0.0	7.6	0.0	0.0	0.0	0.0	6.1	0.0	1.0	28.5	10.7	24.1
15	0.0	35.3	1.5	0.0	22.6	3.3	0.0	0.0	1.0	0.0	0.0	0.0
16	22.6	0.0	0.0	0.0	29.2	52.8	0.0	0.0	0.0	0.0	0.0	0.0
17	5.3	0.0	0.0	0.3	0.0	17.5	5.8	19.1	0.0	0.0	6.9	0.0
18	7.4	0.0	0.0	18.5	6.6	0.0	0.0	0.0	3.3	0.0	0.0	0.0
19	0.6	0.0	6.9	0.0	6.1	3.8	0.0	0.0	0.0	1.5	0.0	2.8

Table A.4 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.0	0.0	0.0	30.5	0.0	0.0	0.0	6.6	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.5	0.0	0.0	19.6	0.5	1.3	27.2	12.5	6.9
22	0.0	21.1	0.0	0.0	9.4	0.0	0.0	0.0	6.6	7.4	13.0	0.8
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	9.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.6	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.5	0.3	0.0	0.0	0.0	0.0	9.7	0.0	0.0	0.0	0.0
27	0.0	1.1	0.4	0.0	0.0	0.0	0.0	20.8	0.0	0.0	0.0	0.0
28	0.0	16.6	0.0	0.0	0.0	0.0	18.3	19.3	0.0	0.0	0.0	0.0
29	0.0	0.0	1.3	34.0		4.1	0.0	0.3	0.0	0.0	15.2	0.0
30	0.0	0.0	13.5	0.0		3.6	0.0	0.0	0.0	0.0	0.0	0.5
31	6.4		26.7	0.0		0.0		0.0		0.0	0.0	

Table A.5. Daily precipitation totals for Water Year 1990 at the 49T station
Units=mm

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	8.1	0.0	0.0	0.0	0.0	3.1	0.0	56.9	0.0	30.2	0.0	0.0
2	0.3	0.0	0.0	0.0	2.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.3	57.9	0.5	0.0	25.9	4.6	0.0	0.0	0.0
4	0.0	0.0	0.0	10.4	6.4	0.0	0.0	13.2	0.0	0.0	19.3	0.0
5	0.0	0.0	0.0	4.3	0.0	0.0	0.0	1.8	0.0	0.0	24.9	0.0
6	0.0	23.2	0.0	4.1	1.0	0.0	17.5	0.5	0.0	0.0	2.8	0.0
7	0.0	15.0	3.3	3.8	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	13.0	11.1	13.5	0.0	4.8	0.0	0.0	0.0	0.0	10.4	0.0
9	0.0	1.3	0.4	0.0	21.6	2.3	0.0	18.3	32.3	0.0	17.3	0.0
10	0.0	0.0	0.0	0.5	18.8	7.6	7.1	4.1	10.9	0.0	0.0	0.0
11	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	26.9	0.0	0.0
12	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	50.8	0.0	5.6
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.2	0.0	1.3
14	0.0	7.6	0.0	0.0	0.0	0.0	5.1	0.0	6.9	17.0	24.6	23.1
15	0.0	37.6	0.6	0.0	18.8	2.8	0.0	0.0	0.0	1.3	0.0	0.0
16	18.8	0.0	0.0	0.0	34.5	53.3	0.0	0.0	0.0	0.0	0.0	0.0
17	19.7	0.0	0.0	0.3	0.0	15.2	5.3	20.8	0.0	0.0	7.9	0.0
18	8.8	0.0	0.0	19.3	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.5	0.0	6.9	0.0	5.3	3.6	0.0	0.0	0.0	4.3	0.3	0.0

Table A.5 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.0	0.0	0.0	30.7	0.0	0.0	0.0	7.1	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	11.2	1.0	0.5	27.9	4.8	6.6
22	0.0	21.0	0.0	0.0	9.1	0.0	0.0	0.0	6.4	4.6	7.6	0.8
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	1.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.5	0.3	0.0	0.0	0.0	0.0	5.1	0.0	0.0	0.0	0.0
27	0.0	1.9	0.0	0.0	0.0	0.0	0.0	14.7	0.0	0.0	0.0	0.0
28	0.0	16.6	0.0	0.0	0.0	0.0	19.1	20.8	0.0	0.0	0.0	0.0
29	0.0	0.0	1.0	33.8		3.3	1.0	0.0	0.0	0.0	22.4	0.0
30	0.0	0.0	13.7	0.0		3.3	0.0	0.0	0.0	0.0	0.0	1.0
31	5.0		29.0	0.0		0.8		0.0		0.0	0.0	

Table A.6. Daily precipitation totals for Water Year 1990 at the NOAA/ATDD station
Units=mm

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	10.4	0.0	0.0	0.0	0.0	5.1	0.0	15.8	0.0	39.6	0.0	0.0
2	0.5	0.0	0.0	0.0	0.0	19.6	0.0	0.5	0.0	1.0	0.3	0.0
3	0.0	0.0	0.0	0.3	58.2	0.5	0.0	25.4	3.6	0.0	0.0	0.0
4	0.0	0.0	0.0	12.5	10.2	0.0	0.0	17.8	0.0	0.0	9.4	0.0
5	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	25.7	0.0
6	0.0	16.0	0.0	2.8	0.8	0.0	18.0	1.0	0.0	0.0	15.8	0.0
7	0.0	12.2	2.5	3.6	2.3	0.0	0.0	0.0	5.8	0.0	0.0	0.3
8	0.0	16.0	13.0	11.7	0.0	3.8	0.0	0.0	0.0	0.0	1.0	0.5
9	0.0	2.3	0.0	0.0	37.3	2.3	0.0	20.1	18.5	0.0	35.8	3.6
10	0.0	0.0	0.0	0.5	17.5	11.9	6.1	5.6	3.6	0.0	0.0	0.0
11	0.0	0.0	1.5	0.0	0.0	1.0	0.0	0.0	0.0	13.0	0.3	0.0
12	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	16.5	0.0	3.6
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.9	0.0	2.8
14	0.0	9.7	0.0	0.0	0.0	0.0	6.4	0.0	0.0	12.5	2.8	9.4
15	0.0	61.0	1.8	0.0	13.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0
16	21.3	0.3	0.0	0.3	37.6	50.8	0.0	0.0	0.0	0.0	0.0	0.0
17	15.8	0.0	0.0	0.0	0.0	19.3	6.1	37.9	0.0	0.0	0.0	0.0
18	8.9	0.0	0.0	21.3	6.6	0.0	0.8	0.0	0.0	0.0	0.0	0.0
19	1.5	0.0	5.3	0.0	5.6	3.8	0.0	0.0	0.0	0.5	0.0	3.8

Table A.6 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.3	0.0	0.0	29.2	0.0	0.0	0.0	2.5	0.0	1.3	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	6.4	1.0	1.3	11.4	13.7	12.7
22	0.0	20.8	0.0	0.0	14.0	0.0	0.0	0.5	6.1	4.6	0.5	0.0
23	0.3	0.5	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	8.6	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	1.0	6.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	1.3	0.0	0.0	0.0	0.0	16.0	0.0	0.0	0.0	0.0
27	0.0	3.6	0.5	0.0	0.0	0.0	0.0	10.9	0.0	0.0	0.0	0.0
28	0.0	11.7	0.0	0.0	0.0	0.0	20.3	11.9	0.0	0.0	0.0	0.0
29	0.0	0.0	4.3	35.6		2.8	0.0	0.5	0.0	0.0	24.1	0.0
30	0.0	0.0	15.5	0.0		5.1	1.3	0.0	0.0	1.3	0.0	0.0
31	3.6		27.7	0.0		0.0		0.0		3.1	0.0	

APPENDIX B

Rating Tables for Monitoring Stations in Whiteoak Creek Watershed

Table B.1 Expanded rating table for First Creek station (USGS 03536450) located on the First Creek tributary to Whiteoak Creek between Burial Ground Road and the confluence with the Northwest tributary

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.3							0.000	0.005	0.007	0.010
0.4	0.015	0.019	0.025	0.031	0.040	0.050	0.058	0.067	0.076	0.088
0.5	0.100	0.112	0.125	0.139	0.155	0.171	0.188	0.206	0.226	0.247
0.6	0.270	0.290	0.312	0.334	0.358	0.383	0.410	0.438	0.467	0.498
0.7	0.530	0.561	0.593	0.626	0.661	0.697	0.734	0.773	0.814	0.856
0.8	0.900	0.937	0.975	1.014	1.055	1.096	1.139	1.182	1.227	1.273
0.9	1.320	1.371	1.424	1.478	1.534	1.591	1.650	1.710	1.772	1.835
1	1.900	1.956	2.014	2.072	2.132	2.192	2.254	2.317	2.381	2.446
1.1	2.512	2.580	2.649	2.719	2.790	2.862	2.936	3.011	3.087	3.164
1.2	3.242	3.322	3.403	3.486	3.57	3.655	3.741	3.829	3.918	4.008
1.3	4.100	4.194	4.289	4.385	4.483	4.582	4.683	4.785	4.888	4.993
1.4	5.100	5.205	5.312	5.420	5.529	5.640	5.752	5.866	5.981	6.098
1.5	6.216	6.335	6.456	6.579	6.703	6.829	6.956	7.084	7.215	7.346
1.6	7.480	7.615	7.751	7.889	8.029	8.170	8.313	8.457	8.603	8.751
1.7	8.900	9.052	9.206	9.362	9.519	9.678	9.839	10.002	10.166	10.332
1.8	10.500	10.655	10.812	10.970	11.13	11.291	11.454	11.617	11.783	11.95

Table B.1 (continued)

INPUT VALUE	GAGE HEIGHT									
1.9	12.118	12.288	12.459	12.632	12.806	12.982	13.159	13.338	13.518	13.7
2	13.883	14.068	14.254	14.442	14.631	14.822	15.015	15.209	15.404	15.601
2.1	15.800	16.086	16.375	16.669	16.966	17.267	17.573	17.882	18.195	18.512
2.2	18.833	19.158	19.487	19.821	20.158	20.5	20.875	21.255	21.64	22.03
2.3	22.426	22.827	23.233	23.645	24.062	24.485	24.914	25.348	25.787	26.233
2.4	26.684	27.141	27.604	28.073	28.548	29.029	29.516	30.01	30.509	31.015
2.5	31.527	32.045	32.570	33.101	33.639	34.183	34.734	35.292	35.856	36.427
2.6	37.005	37.590	38.182	38.781	39.387	40	40.83	41.673	42.531	43.403
2.7	44.290	45.192	46.108	47.039	47.986	48.949	49.927	50.921	51.931	52.957
2.8	54.000	54.962	55.938	56.927	57.931	58.948	59.98	61.026	62.086	63.161
2.9	64.251	65.356	66.477	67.612	68.763	69.929	71.111	72.309	73.523	74.753
3	76.000	77.239	78.494	79.765	81.053	82.357	83.678	85.015	86.369	87.741
3.1	89.130	90.536	91.959	93.400	94.86	96.337	97.832	99.346	100.879	102.43
3.2	104.000	105.564	107.147	108.749	110.369	112.009	113.667	115.345	117.043	118.76
3.3	120.497	122.255	124.032	125.830	127.648	129.487	131.347	133.228	135.131	137.054
3.4	139.000									

Offset = 0.00 (0.36); Rating No. = 2.0; Type = 001

Table B.2 Expanded rating table for 7500 Bridge station (USGS 03536550) located on Whiteoak Creek below Melton Valley Drive

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2.1									0.000	0.069
2.2	0.138	0.207	0.276	0.345	0.414	0.483	0.552	0.621	0.690	0.759
2.3	0.828	0.897	0.966	1.035	1.104	1.173	1.242	1.311	1.380	1.472
2.4	1.567	1.665	1.767	1.873	1.983	2.096	2.213	2.334	2.459	2.587
2.5	2.72	2.856	2.997	3.141	3.29	3.443	3.6	3.761	3.926	4.097
2.6	4.269	4.447	4.629	4.816	5.008	5.203	5.403	5.608	5.817	6.031
2.7	6.249	6.473	6.7	6.933	7.17	7.412	7.659	7.91	8.167	8.428
2.8	8.694	8.965	9.241	9.523	9.809	10.1	10.406	10.718	11.035	11.358
2.9	11.687	12.021	12.361	12.707	13.059	13.417	13.78	14.15	14.525	14.907
3.0	15.294	15.688	16.087	16.493	16.905	17.323	17.747	18.178	18.615	19.058
3.1	19.508	19.964	20.426	20.895	21.37	21.852	22.34	22.835	23.337	23.845
3.2	24.36	24.882	25.41	25.945	26.487	27.036	27.592	28.154	28.724	29.300
3.3	29.884	30.474	31.072	31.676	32.288	32.906	33.532	34.165	34.806	35.453
3.4	36.108	36.77	37.44	38.117	38.801	39.493	40.192	40.898	41.612	42.334
3.5	43.063	43.8	44.504	45.215	45.933	46.657	47.388	48.125	48.87	49.621
3.6	50.378	51.143	51.914	52.692	53.476	54.268	55.066	55.871	56.684	57.502
3.7	58.328	59.161	60.001	60.847	61.701	62.562	63.429	64.304	65.185	66.074
3.8	66.97	67.872	68.782	69.699	70.623	71.555	72.493	73.439	74.391	75.351

Table B.2 (continued)

INPUT VALUE	GAGE HEIGHT									
3.9	76.319	77.293	78.275	79.264	80.26	81.264	82.275	83.293	84.319	85.351
4.0	86.392	87.439	88.495	89.557	90.627	91.705	92.79	93.882	94.982	96.090
4.1	97.205	98.327	99.457	100.595	101.74	102.893	104.053	105.222	106.398	107.581
4.2	108.772	109.971	111.178	112.392	113.614	114.843	116.081	117.326	118.580	119.840
4.3	121.109	122.386	123.67	124.963	126.263	127.571	128.887	130.211	131.543	132.883
4.4	134.231	135.586	136.95	138.322	139.702	141.09	142.486	143.89	145.302	146.722
4.5	148.15	149.586	151.031	152.484	153.944	155.413	156.89	158.376	159.869	161.371
4.6	162.881	164.4	165.926	167.461	169.004	170.555	172.115	173.683	175.260	176.844
4.7	178.437	180.039	181.649	183.267	184.894	186.529	188.173	189.825	191.486	193.155
4.8	194.832	196.518	198.213	199.916	201.628	203.348	205.077	206.814	208.560	210.315
4.9	212.078	213.85	215.63	217.419	219.217	221.024	222.839	224.663	226.496	228.337
5.0	230.187	232.046	233.914	235.79	237.675	239.57	241.472	243.384	245.305	247.234
5.1	249.173	251.12	253.076	255.041	257.015	258.997	260.989	262.990	265.000	267.474
5.2	269.965	272.47	274.991	277.528	280.08	282.647	285.230	287.828	290.442	293.072
5.3	295.718	298.379	301.056	303.749	306.458	309.182	311.923	314.680	317.453	320.242
5.4	323.047	325.869	328.706	331.56	334.431	337.318	340.221	343.141	346.077	349.030
5.5	352	354.987	357.992	361.014	364.053	367.108	370.181	373.270	376.376	379.500
5.6	382.641	385.799	388.974	392.166	395.376	398.602	401.847	405.109	408.388	411.685
5.7	415	418.058	421.132	424.219	427.322	430.438	433.569	436.714	439.873	443.047

Table B.2 (continued)

INPUT VALUE	GAGE HEIGHT									
5.8	446.236	449.438	452.655	455.887	459.134	462.394	465.670	468.960	472.265	475.585
5.9	478.919	482.268	485.632	489.01	492.404	495.812	499.235	502.674	506.126	509.594
6.0	513.078	516.575	520.088	523.616	527.16	530.718	534.292	537.880	541.484	545.103
6.1	548.738	552.388	556.052	559.733	563.429	567.139	570.866	574.608	578.366	582.138
6.2	585.927	589.731	593.551	597.386	601.237	605.103	608.986	612.883	616.797	620.726
6.3	624.672	628.633	632.61	636.603	640.612	644.636	648.677	652.733	656.806	660.894
6.4	665.000									

Offset = 2.00

Table B.3 Expanded rating table for H-flume weir at Center Seven station located on Center 7 Creek, a tributary of Melton Branch

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.000	0.001	0.002	0.004	0.006	0.009	0.012	0.016	0.02	0.025
0.1	0.030	0.035	0.041	0.047	0.053	0.059	0.067	0.074	0.082	0.091
0.2	0.099	0.108	0.118	0.128	0.138	0.149	0.16	0.172	0.184	0.196
0.3	0.209	0.222	0.235	0.249	0.264	0.28	0.296	0.312	0.329	0.346
0.4	0.364	0.382	0.4	0.419	0.437	0.455	0.477	0.498	0.52	0.542
0.5	0.565	0.588	0.61	0.634	0.66	0.685	0.71	0.736	0.763	0.791
0.6	0.819	0.847	0.876	0.905	0.934	0.964	0.995	1.026	1.095	1.095
0.7	1.13	1.162	1.195	1.229	1.264	1.299	1.338	1.376	1.414	1.452
0.8	1.49	1.53	1.569	1.611	1.655	1.698	1.741	1.783	1.828	1.874
0.9	1.921	1.966	2.011	2.059	2.11	2.161	2.21	2.26	2.31	2.361
1.0	2.412	2.463	2.513	2.567	2.624	2.68	2.737	2.793	2.851	2.91
1.1	2.97	3.03	3.091	3.151	3.21	3.27	3.333	3.397	3.463	3.532
1.2	3.602	3.672	3.743	3.806	3.863	3.919	3.99	4.061	4.131	4.202
1.3	4.273	4.357	4.442	4.52	4.59	4.661	4.746	4.83	4.908	4.979
1.4	5.049	5.134	5.219	5.304	5.388	5.473	5.558	5.643	5.727	5.812
1.5	5.897	5.982	6.066	6.158	6.257	6.356	6.455	6.554	6.652	6.751
1.6	6.85	6.949	7.048	7.147	7.246	7.344	7.443	7.542	7.648	7.761

Table B.3 (continued)

1.7	7.874	7.973	8.072	8.178	8.291	8.404	8.517	8.63	8.743	8.856
1.8	8.969	9.096	9.223	9.343	9.456	9.569	9.696	9.823	9.95	10.077
1.9	10.205	10.318	10.431	10.551	10.678	10.805	10.946	11.087	11.229	11.37
2.0	11.511	11.652	11.794	11.935	12.076	12.217	12.344	12.471	12.606	12.747
2.1	12.888	13.029	13.171	13.312	13.453	13.594	13.75	13.905	14.06	14.216
2.2	14.371	14.527	14.682	14.837	14.993	15.148	15.303	15.459	15.621	15.791
2.3	15.96	16.13	16.299	16.462	16.617	16.772	16.942	17.111	17.281	17.45
2.4	17.62	17.803	17.987	18.163	18.333	18.502	18.686	18.87	19.046	19.216
2.5	19.385									

Table B.4 Expanded rating table for V-notch flume weir at Center Seven station located on Center 7 Creek, a tributary of Melton Branch

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.005	0.006
0.1	0.008	0.010	0.012	0.015	0.018	0.022	0.026	0.03	0.034	0.039
0.2	0.045	0.051	0.057	0.063	0.071	0.078	0.086	0.095	0.104	0.113
0.3	0.123	0.134	0.145	0.156	0.169	0.181	0.194	0.208	0.223	0.237
0.4	0.253	0.283	0.324	0.374	0.429	0.490	0.557	0.627	0.702	0.781
0.5	0.864	0.950	1.039	1.132	1.227	1.326	1.428	1.532	1.639	1.749
0.6	1.861	1.976	2.093	2.213	2.335	2.459	2.585	2.714	2.844	2.977
0.7	3.112	3.248	3.387	3.528	3.670	3.815	3.961	4.109	4.259	4.410
0.8	4.564	4.719	4.875	5.034	5.194	5.355	5.518	5.683	5.849	6.017
0.9	6.187	6.358	6.530	6.704	6.879	7.056	7.234	7.413	7.594	7.776
1.0	7.960									

Table B.5 Expanded rating table for East Seven Tributary station on Melton Branch adjacent to proposed SWSA 7

INPUT VALUE	GAGE HEIGHT									
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
1.0	0.000	0.001	0.003	0.004	0.006	0.007	0.009	0.012	0.016	0.022
1.1	0.029	0.034	0.039	0.045	0.051	0.057	0.064	0.072	0.080	0.087
1.2	0.094	0.102	0.111	0.120	0.129	0.138	0.149	0.160	0.169	0.179
1.3	0.190	0.201	0.212	0.224	0.237	0.250	0.263	0.277	0.291	0.305
1.4	0.321	0.337	0.354	0.371	0.389	0.408	0.428	0.448	0.470	0.492
1.5	0.515	0.539	0.564	0.585	0.607	0.630	0.653	0.677	0.701	0.726
1.6	0.753	0.779	0.807	0.835	0.865	0.895	0.926	0.957	0.990	1.024
1.7	1.058	1.094	1.130	1.162	1.195	1.228	1.262	1.297	1.333	1.370
1.8	1.407	1.445	1.484	1.523	1.564	1.605	1.648	1.691	1.735	1.780
1.9	1.826	1.872	1.920	1.965	2.011	2.058	2.106	2.154	2.204	2.254
2.0	2.305	2.357	2.410	2.461	2.512	2.564	2.617	2.671	2.725	2.781
2.1	2.837	2.894	2.952	3.011	3.071	3.132	3.194	3.256	3.320	3.384
2.2	3.450	3.516	3.583	3.652	3.721	3.791	3.863	3.935	4.008	4.083
2.3	4.158	4.235	4.312	4.391	4.471	4.551	4.633	4.716	4.801	4.886
2.4	4.972	5.060	5.139	5.218	5.298	5.379	5.461	5.545	5.628	5.713
2.5	5.799	5.886	5.973	6.062	6.152	6.242	6.334	6.426	6.520	6.614
2.6	6.710	6.806	6.904	7.002	7.102	7.202	7.304	7.406	7.510	7.615
2.7	7.720	7.827	7.935	8.044	8.154	8.266	8.378	8.491	8.606	8.722

Table B.5 (continued)

INPUT VALUE	GAGE HEIGHT									
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
1.0	0.000	0.001	0.003	0.004	0.006	0.007	0.009	0.012	0.016	0.022
2.8	8.838	8.956	9.075	9.196	9.317	9.440	9.563	9.688	9.814	9.942
2.9	10.070	10.200	10.339	10.479	10.620	10.763	10.908	11.054	11.201	11.350
3.0	11.500	11.631	11.763	11.896	12.030	12.165	12.301	12.438	12.576	12.716
3.1	12.856	12.998	13.140	13.284	13.429	13.575	213.722	13.870	14.020	14.170
3.2	14.322	14.474	14.628	14.783	14.940	15.097	15.255	15.415	15.576	15.738
3.3	15.901	16.066	16.231	16.398	16.566	16.735	16.906	17.078	17.250	17.425
3.4	17.600	17.784	17.969	18.155	18.343	18.533	18.723	18.915	19.109	19.304
3.5	19.500	19.750	20.003	20.259	20.516	20.777	21.040	21.305	21.573	21.844
3.6	22.118	22.394	22.672	22.954	23.238	23.524	23.814	24.106	24.401	24.699
3.7	25.000									

Table B.6 Expanded rating table for East Seep station located on the east seep tributary to the headwaters of Whiteoak Creek

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.2	0.052	0.058	0.065	0.072	0.08	0.088	0.096	0.105	0.115	0.124
0.3	0.135	0.146	0.157	0.169	0.181	0.194	0.207	0.221	0.235	0.25
0.4	0.266	0.281	0.298	0.315	0.332	0.351	0.369	0.388	0.408	0.429
0.5	0.449	0.471	0.493	0.516	0.539	0.563	0.587	0.612	0.638	0.664
0.6	0.691	0.718	0.746	0.775	0.804	0.834	0.865	0.896	0.928	0.96
0.7	0.994	1.027	1.062	1.097	1.133	1.169	1.206	1.244	1.282	1.322
0.8	1.361	1.402	1.443	1.485	1.527	1.571	1.614	1.659	1.704	1.75
0.9	1.797	1.845	1.893	1.942	1.991	2.042	2.093	2.144	2.197	2.25
1	2.304	2.359	2.414	2.47	2.527	2.585	2.643	2.703	2.762	2.823
1.1	2.885	2.947	3.01	3.074	3.138	3.203	3.269	3.336	3.404	3.472
1.2	3.542	3.612	3.682	3.754	3.826	3.899	3.973	4.048	4.124	4.2
1.3	4.277	4.355	4.434	4.514	4.594	4.675	4.757	4.84	4.924	5.009
1.4	5.094	5.18	5.267	5.355	5.444	5.533	5.624	5.715	5.807	5.9
1.5	5.994	6.088	6.184	6.28	6.378	6.476	6.575	6.674	6.775	6.877
1.6	6.979	7.082	7.187	7.292	7.397	7.504	7.612	7.721	7.83	7.94
1.7	8.052	8.164	8.277	8.391	8.505	8.621	8.738	8.855	8.974	9.093
1.8	9.213	9.334	9.457	9.579	9.703	9.828	9.954	10.081	10.208	

Table B.7 Expanded rating table for flume at station on tributary to Melton Branch near the old Homogeneous Reactor Test facility

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.2	0.05	0.056	0.062	0.069	0.076	0.084	0.092	0.101	0.11	0.119
0.3	0.129	0.139	0.15	0.161	0.173	0.185	0.198	0.211	0.225	0.239
0.4	0.253	0.269	0.284	0.3	0.317	0.334	0.352	0.37	0.389	0.408
0.5	0.428	0.448	0.469	0.491	0.513	0.535	0.558	0.582	0.606	0.631
0.6	0.656	0.682	0.709	0.736	0.764	0.792	0.821	0.85	0.881	0.911
0.7	0.943	0.974	1.007	1.04	1.074	1.108	1.143	1.179	1.215	1.252
0.8	1.289	1.328	1.366	1.406	1.446	1.487	1.528	1.57	1.613	1.656
0.9	1.7	1.745	1.79	1.836	1.883	1.93	1.978	2.027	2.076	2.126
1.0	2.177	2.228	2.281	2.333	2.387	2.441	2.496	2.552	2.608	2.665
1.1	2.723	2.781	2.840	2.900	2.961	3.022	3.084	3.147	3.21	3.275
1.2	3.340	3.405	3.472	3.539	3.607	3.675	3.745	3.815	3.886	3.957
1.3	4.030	4.103	4.177	4.251	4.327	4.403	4.48	4.558	4.636	4.715
1.4	4.795	4.876	4.958	5.04	5.123	5.207	5.292	5.377	5.463	5.55
1.5	5.638									

Table B.8 Expanded rating table for Ish Creek station located upstream from the mouth of the Clinch River at kilometer 30.7 (mile 19.1)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0							0.001	0.001	0.002	0.003
0.1	0.004	0.005	0.006	0.007	0.008	0.01	0.012	0.014	0.016	0.018
0.2	0.021	0.024	0.027	0.03	0.033	0.037	0.041	0.046	0.05	0.055
0.3	0.059	0.065	0.07	0.076	0.082	0.088	0.094	0.101	0.109	0.116
0.4	0.123	0.132	0.14	0.149	0.158	0.166	0.174	0.182	0.19	0.198
0.5	0.206	0.217	0.227	0.238	0.248	0.259	0.27	0.28	0.291	0.301
0.6	0.312	0.326	0.341	0.355	0.37	0.384	0.398	0.413	0.427	0.442
0.7	0.456	0.472	0.488	0.505	0.521	0.537	0.553	0.569	0.586	0.602
0.8	0.618	0.639	0.66	0.682	0.703	0.724	0.745	0.766	0.788	0.809
0.9	0.83	0.86	0.89	0.92	0.95	0.98	1.01	1.04	1.07	1.1
1	1.13	1.167	1.204	1.241	1.278	1.315	1.352	1.389	1.426	1.463
1.1	1.5	1.544	1.588	1.632	1.676	1.72	1.764	1.808	1.852	1.896
1.2	1.94	1.993	2.046	2.099	2.152	2.205	2.258	2.311	2.364	2.417
1.3	2.47	2.576	2.682	2.788	2.894	3	3.106	3.212	3.318	3.424
1.4	3.53	3.689	3.848	4.007	4.166	4.325	4.484	4.643	4.802	4.961
1.5	5.12	5.35	5.58	5.81	6.04	6.27	6.5	6.73	6.96	7.19
1.6	7.42	7.738	8.056	8.374	8.692	9.01	9.328	9.646	9.964	10.282

Table B.8 (continued)

INPUT VALUE	GAGE HEIGHT									
1.7	10.6	10.99	11.38	11.77	12.16	12.55	12.94	13.33	13.72	14.11
1.8	14.5	14.97	15.44	15.91	16.38	16.85	17.32	17.79	18.26	18.73
1.9	19.2	19.75	20.3	20.85	21.4	21.95	22.5	23.05	23.6	24.15
2	24.7	25.34	25.98	26.62	27.26	27.9	28.54	29.18	29.82	30.46
2.1	31.1	31.84	32.58	33.32	34.06	34.8	35.54	36.28	37.02	37.76
2.2	38.5	39.31	40.12	40.93	41.74	42.55	43.36	44.17	44.98	45.79
2.3	46.6	47.45	48.3	49.15	50	50.85	51.7	52.55	53.4	54.25
2.4	55.1	56.02	56.94	57.86	58.78	59.7	60.62	61.54	62.46	63.38
2.5	64.3	65.25	66.2	67.15	68.1	69.05	70	70.95	71.9	72.85
2.6	73.8	74.82	75.84	76.86	77.88	78.9	79.92	80.94	81.96	82.98
2.7	84	85.06	86.12	87.18	88.24	89.3	90.36	91.42	92.48	93.54
2.8	94.6	95.74	96.88	98.02	99.16	100.3	101.44	102.58	103.72	104.86
2.9	106	107.2	108.4	109.6	110.8	112	113.2	114.4	115.6	116.8
3	118									

Table B.9 Expanded rating table for Melton Branch 2 (MB2) upstream fromm the confluence with the HRT tributary

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.2	1.8	1.932	2.066	2.203	2.343	2.486	2.631	2.778	2.928	3.081
0.3	3.235	3.392	3.552	3.713	3.877	4.043	4.211	4.381	4.554	4.728
0.4	4.904	5.083	5.263	5.445	5.629	5.815	6.003	6.192	6.384	6.577
0.5	6.772	6.969	7.167	7.367	7.569	7.773	7.978	8.184	8.393	8.603
0.6	8.815	9.028	9.243	9.459	9.677	9.896	10.117	10.34	10.563	10.789
0.7	11.016	11.244	11.474	11.705	11.937	12.171	12.407	12.643	12.881	13.121
0.8	13.362	13.604	13.847	14.092	14.339	14.586	14.835	15.085	15.336	15.589
0.9	15.843	16.098	16.354	16.612	16.871	17.131	17.392	17.655	17.919	18.184
1	18.45	18.717	18.986	19.256	19.527	19.799	20.072	20.346	20.622	20.898
1.1	21.176	21.455	21.735	22.016	22.299	22.582	22.867	23.152	23.439	23.727
1.2	24.016	24.305	24.596	24.889	25.182	25.476	25.771	26.067	26.365	26.663
1.3	26.962	27.263	27.564	27.867	28.17	28.475	28.78	29.087	29.394	29.703
1.4	30.012	30.323	30.634	30.947	31.26	31.574	31.89	32.206	32.523	32.842
1.5	33.161									

Table B.10 Expanded rating table at low flow for Melton Branch (MB) station located above the confluence with Whiteoak Creek

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.2	0.074	0.083	0.094	0.105	0.117	0.13	0.144	0.158	0.173	0.189
0.3	0.207	0.224	0.243	0.263	0.284	0.306	0.328	0.352	0.377	0.402
0.4	0.429	0.457	0.486	0.516	0.547	0.579	0.612	0.647	0.682	0.719
0.5	0.757	0.796	0.836	0.878	0.921	0.965	1.01	1.056	1.104	1.153
0.6	1.204	1.255	1.308	1.363	1.418	1.475	1.534	1.593	1.655	1.717
0.7	1.781	1.847	1.914	1.982	2.052	2.123	2.196	2.27	2.345	2.423
0.8	2.501	2.582	2.664	2.747	2.832	2.918	3.007	3.096	3.188	3.28
0.9	3.375	3.471	3.569	3.668	3.77	3.872	3.977	4.083	4.191	4.301
1	4.412	4.525	4.64	4.756	4.875	4.995	5.117	5.24	5.366	5.493
1.1	5.622	5.753	5.886	6.02	6.157	6.295	6.435	6.577	6.721	6.867
1.2	7.014	7.164	7.316	7.469	7.624	7.782	7.941	8.102	8.266	8.431
1.3	8.598	8.767	8.938	9.112	9.287	9.464	9.643	9.825	10.008	10.193
1.4	10.381	10.571	10.762	10.956	11.152	11.35	11.55	11.752	11.957	12.163
1.5	12.372	12.583	12.796	13.011	13.228	13.448	13.669	13.893	14.12	14.348
1.6	14.578	14.811	15.046	15.284	15.523	15.765	16.009	16.256	16.504	16.755
1.7	17.009	17.264	17.522	17.782	18.045	18.31	18.577	18.847	19.118	19.393
1.8	19.67	19.949	20.23	20.514	20.8	21.089	21.38	21.673	21.969	22.268

Table B.10 (continued)

INPUT VALUE	GAGE HEIGHT									
1.9	22.569	22.872	23.178	23.486	23.797	24.11	24.425	24.744	25.064	25.387
2	25.713	26.041	26.372	26.705	27.041	27.38	27.72	28.064	28.41	28.759
2.1	29.11	29.464	29.82	30.179	30.541	30.905	31.272	31.641	32.013	32.388
2.2	32.765	33.146	33.528	33.914	34.302	34.693				

Table B.11 Expanded rating table for North West Tributary (NWT) station located above the confluence with First Creek

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.1								0.100	0.114	0.128
0.2	0.144	0.161	0.179	0.197	0.217	0.238	0.26	0.283	0.307	0.332
0.3	0.359	0.386	0.415	0.444	0.475	0.507	0.541	0.575	0.61	0.647
0.4	0.685	0.724	0.765	0.806	0.849	0.893	0.938	0.985	1.032	1.081
0.5	1.132	1.183	1.236	1.29	1.345	1.402	1.46	1.519	1.58	1.642
0.6	1.705	1.77	1.836	1.903	1.971	2.041	2.113	2.185	2.259	2.335
0.7	2.412	2.49	2.569	2.65	2.733	2.816	2.901	2.988	3.076	3.165
0.8	3.256	3.349	3.442	3.537	3.634	3.732	3.831	3.932	4.035	4.139
0.9	4.244	4.351	4.459	4.569	4.68	4.793	4.907	5.022	5.14	5.258
1	5.379	5.5	5.623	5.748	5.874	6.002	6.132	6.262	6.395	6.529
1.1	6.664	6.801	6.94	7.08	7.222	7.365	7.51	7.656	7.804	7.954
1.2	8.105	8.257	8.412	8.567	8.725	8.884	9.045	9.207	9.371	9.536
1.3	9.703	9.872	10.042	10.214	10.387	10.563	10.739	10.918	11.098	11.28
1.4	11.463	11.648	11.834	12.023	12.213	12.404	12.597	12.792	12.989	13.187
1.5	13.387	13.588	13.792	13.996	14.203	14.411	14.621	14.833	15.046	15.261
1.6	15.478	15.696	15.916	16.138	16.362	16.587	16.814	17.043	17.273	17.505
1.7	17.739	17.974	18.212	18.451	18.691	18.934	19.178	19.424	19.672	19.921

Table B.11 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1.8	20.172	20.425	20.68	20.936	21.194	21.454	21.716	21.979	22.244	22.511
1.9	22.78	23.051	23.323	23.597	23.873	24.151	24.43	24.711	24.994	25.279
2	25.566	25.854	26.144	26.436	26.73	27.025	27.323	27.622	27.923	28.226
2.1	28.53	28.837	29.145	29.455	29.767	30.081	30.396	30.714	31.033	31.354
2.2	31.677	32.002	32.328	32.657	32.987	33.319	33.653	33.989	34.327	34.666
2.3	35.007	35.351	35.696	36.043	36.392	36.742	37.095	37.449	37.805	38.164
2.4	38.524	38.886	39.249	39.615	39.983	40.352	40.724	41.097	41.472	41.849
2.5	42.228	42.609	42.991	43.376	43.763	44.151	44.541	44.933	45.328	45.724
2.6	46.122	46.522	46.923	47.327	47.733	48.14	48.55	48.961	49.375	49.79
2.7	50.207	50.626	51.047	51.471	51.896	52.322	52.751	53.182	53.615	54.05
2.8	54.486	54.925	55.365	55.808	56.252	56.699	57.147	57.597	58.05	58.504
2.9	58.96	59.419	59.879	60.341	60.805	61.271	61.739	62.209	62.681	63.155
3	63.631	64.109	64.589	65.071	65.555	66.041	66.529	67.019	67.511	68.005
3.1	68.501	68.999	69.499	70.001	70.505	71.011	71.519	72.029	72.541	73.055
3.2	73.571	74.089	74.609	75.131	75.655	76.181	76.71	77.24	77.772	78.306
3.3	78.842	79.381	79.921	80.464	81.008	81.554	82.103	82.654	83.206	83.761
3.4	84.317	84.876	85.437	86						

Table B.12 Expanded rating table for Raccoon Creek station

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0.001	0.002	0.003	0.003						
0.1	0.004	0.005	0.007	0.008	0.01	0.012	0.014	0.016	0.019	0.022
0.2	0.025	0.028	0.031	0.035	0.039	0.043	0.047	0.052	0.057	0.062
0.3	0.066	0.073	0.079	0.085	0.091	0.098	0.105	0.113	0.121	0.128
0.4	0.136	0.145	0.154	0.162	0.171	0.18	0.191	0.202	0.212	0.223
0.5	0.234	0.247	0.259	0.272	0.284	0.297	0.311	0.326	0.34	0.355
0.6	0.369	0.385	0.402	0.418	0.435	0.451	0.469	0.488	0.506	0.525
0.7	0.543	0.563	0.584	0.604	0.625	0.645	0.668	0.69	0.713	0.735
0.8	0.758	0.783	0.808	0.833	0.858	0.883	0.91	0.937	0.964	0.991
0.9	1.018	1.048	1.077	1.107	1.136	1.166	1.198	1.23	1.261	1.293
1	1.325	1.359	1.394	1.482	1.463	1.497	1.534	1.571	1.608	1.645
1.1	1.682	1.721	1.761	1.8	1.84	1.879	1.921	1.963	2.006	2.048
1.2	2.09	2.135	2.18	2.225	2.27	2.315	2.445	2.575	2.705	2.835
1.3	2.965	3.165	3.365	3.564	3.764	3.964	4.209	4.454	4.699	4.944
1.4	5.189	5.47	5.751	6.032	6.313	6.594	6.906	7.218	7.53	7.842
1.5	8.154	8.493	8.832	9.171	9.51	9.849	10.213	10.577	10.942	11.306
1.6	11.67	12.056	12.442	12.828	13.214	13.6	14.006	14.412	14.818	15.224

Table B.12 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1.7	15.63	16.054	16.478	16.902	17.326	17.75	18.194	18.638	19.082	19.526
1.8	19.97	20.428	20.886	21.344	21.802	22.26	22.736	23.212	23.688	24.164
1.9	24.64	25.128	25.616	26.104	26.592	27.08	27.584	28.088	28.592	29.096
2	29.6	30.123	30.646	31.169	31.692	32.215	32.738	33.261	33.784	34.307
2.1	34.83	35.376	35.922	36.468	37.014	37.56	38.106	38.652	39.198	39.744
2.2	40.29	40.857	41.424	41.991	42.558	43.125	43.692	44.259	44.826	45.393
2.3	45.96	46.547	47.114	47.681	48.248	49.815	50.382	50.949	51.516	52.083
2.4	51.83	52.435	53.04	53.645	54.25	54.855	55.46	56.065	56.67	57.275
2.5	57.88									

Table B.13 Expanded rating table for T-2A station located on an unnamed tributary to Whiteoak Creek near the southern boundary of SWSA 4

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.2	0.16	0.18	0.19	0.2	0.22	0.23	0.24	0.26	0.29	0.3
0.3	0.31	0.33	0.35	0.37	0.39	0.42	0.44	0.46	0.48	0.51
0.4	0.54	0.56	0.59	0.62	0.65	0.68	0.71	0.74	0.78	0.81
0.5	0.84	0.88	0.92	0.95	0.99	1.03	1.07	1.11	1.16	1.2
0.6	1.24	1.29	1.34	1.38	1.43	1.48	1.53	1.58	1.64	1.69
0.7	1.74	1.8	1.86	1.92	1.97	2.03	2.1	2.16	2.22	2.29
0.8	2.35	2.42	2.49	2.56	2.63	2.7	2.77	2.84	2.92	3
0.9	3.07	3.15	3.23	3.31	3.39	3.48	3.56	3.65	3.74	3.82
1	3.91	4	4.1	4.19	4.28	4.38	4.48	4.58	4.68	4.78
1.1	4.88	4.98	5.09	5.2	5.3	5.41	5.52	5.63	5.75	5.86
1.2	5.98	6.1	6.21	6.33	6.46	6.58	6.7	6.83	6.96	7.08

Manufacturer's rating for the trapezoidal flume at T-2A is:

$$Q = 2.32 \times H^{2.5} + 0.63 \times H^{1.5} + 0.05 \text{ for } H = 0.20 \text{ to } 1.29 \text{ ft}$$

where Q = discharge (cfs), H = stage (ft)

Table B.14 Expanded rating table for Upper Whiteoak Creek station (GS6, USGS 03536320) east of the East gate of ORNL and near Building 6000

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.2									0.000	0.001
0.3	0.002	0.004	0.007	0.01	0.013	0.016	0.02	0.024	0.03	0.035
0.4	0.042	0.049	0.057	0.066	0.077	0.089	0.101	0.114	0.129	0.146
0.5	0.164	0.184	0.206	0.229	0.256	0.284	0.316	0.35	0.387	0.427
0.6	0.471	0.518	0.569	0.624	0.684	0.748	0.817	0.891	0.971	1.057
0.7	1.149	1.247	1.352	1.464	1.584	1.712	1.849	1.994	2.149	2.313
0.8	2.488	2.674	2.87	3.079	3.3	3.534	3.782	4.043	4.32	4.612
0.9	4.92	5.2	5.493	5.799	6.119	6.452	6.8	7.15	7.515	7.894
1	8.288	8.698	9.123	9.565	10.024	10.5	10.931	11.375	11.833	12.304
1.1	12.79	13.291	13.806	14.337	14.883	15.444	16.022	16.616	17.227	17.855
1.2	18.5	19.024	19.558	20.103	20.659	21.225	21.802	22.389	22.988	23.598
1.3	24.22	24.852	25.497	26.153	26.82	27.5	28.13	28.77	29.419	30.078
1.4	30.748	31.427	32.116	32.815	33.525	34.244	34.975	35.715	36.466	37.228
1.5	38	38.785	39.58	40.386	41.204	42.032	42.872	43.723	44.585	45.458
1.6	46.343	47.24	48.148	49.068	50	50.92	51.852	52.795	53.75	54.715
1.7	55.693	56.682	57.682	58.694	59.718	60.754	61.802	62.862	63.934	65.017
1.8	66.113	67.222	68.343	69.476	70.621	71.779	72.95	74.133	75.329	76.538
1.9	77.76	78.994	80.242	81.503	82.776	84.063	85.364	86.677	88.004	89.345

Table B.14 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2	90.699	92.067	93.448	94.843	96.252	97.675	99.112	100.563	102.027	103.507
2.1	105	106.387	107.787	109.197	110.62	112.055	113.501	114.959	116.429	117.911
2.2	119.405	120.911	122.429	123.959	125.501	127.056	128.622	130.201	131.793	133.396
2.3	135.012	136.641	138.282	139.935	141.601	143.28	144.971	146.675	148.392	150.121
2.4	151.864	153.619	155.387	157.168	158.962	160.768	162.589	164.422	166.268	168.127
2.5	170	172.008	174.031	176.07	178.125	180.196	182.283	184.385	186.503	188.638
2.6	190.788	192.955	195.137	197.336	199.551	201.783	204.031	206.295	208.576	210.874
2.7	213.188	215.519	217.867	220.231	222.613	225.011	227.426	229.858	232.308	234.775
2.8	237.258	239.759	242.278	244.814	247.367	249.938	252.526	255.132	257.756	260.397
2.9	263.057	265.734	268.429	271.142	273.873	276.622	279.389	282.175	284.979	287.801
3	290.641	293.5	296.378	299.274	302.188	305.121	308.074	311.044	314.034	317.043
3.1	320.07	323.117	326.182	329.267	332.371	335.494	338.637	341.799	344.980	348.181
3.2	351.401	354.641	357.901	361.18	364.479	367.798	371.136	374.495	377.874	381.273
3.3	384.692	388.131	391.59	395.07	398.569	402.09	405.63	409.192	412.774	416.376
3.4	420									

Offset=0.00

Table B.15 Expanded rating table for West Seven Tributary station (GS17, USGS 03537200) located on Melton Branch

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1			0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.006
1.1	0.007	0.007	0.008	0.01	0.012	0.015	0.018	0.022	0.025	0.029
1.2	0.034	0.039	0.045	0.05	0.056	0.063	0.07	0.078	0.086	0.094
1.3	0.103	0.112	0.123	0.133	0.144	0.155	0.168	0.181	0.194	0.207
1.4	0.222	0.237	0.253	0.293	0.338	0.39	0.45	0.503	0.562	0.627
1.5	0.7	0.772	0.85	0.92	0.995	1.075	1.162	1.255	1.354	1.461
1.6	1.576	1.699	1.83	1.93	2.035	2.144	2.259	2.379	2.505	2.637
1.7	2.775	2.919	3.07	3.194	3.321	3.453	3.59	3.731	3.877	4.028
1.8	4.183	4.344	4.51	4.654	4.802	4.954	5.109	5.269	5.432	5.600
1.9	5.773	5.949	6.13	6.292	6.457	6.626	6.799	6.975	7.154	7.337
2	7.525	7.715	7.91	8.088	8.27	8.455	8.643	8.834	9.028	9.226
2.1	9.427	9.632	9.84	10.045	10.254	10.466	10.681	10.9	11.412	11.945
2.2	12.5	12.86	13.228	13.605	13.991	14.386	14.791	15.205	15.629	16.063
2.3	16.507	16.961	17.425	17.9	18.386	18.883	19.392	19.911	20.443	20.986
2.4	21.541	22.109	22.689	23.282	23.887	24.506	25.139	25.785	26.445	27.119
2.5	27.807	28.51	29.228	29.961	30.71	31.474	32.254	33.05	33.862	34.692
2.6	35.538	36.402	37.283	38.182	39.099	40.035	40.989	41.962	42.955	43.968

Table B.15 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2.7	45									

Table B.16 Expanded rating table for high flow at Whiteoak Creek station (WOC) located above the confluence with Melton Branch

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.2	8.838	9.542	10.265	11.007	11.768	12.546	13.343	14.158	14.99	15.839
0.3	16.705	17.587	18.486	19.401	20.332	21.279	22.241	23.218	24.211	25.219
0.4	26.242	27.279	28.331	29.397	30.477	31.572	32.68	33.802	34.938	36.088
0.5	37.251	38.427	39.617	40.82	42.035	43.264	44.505	45.759	47.026	48.305
0.6	49.597	50.901	52.217	53.545	54.886	56.238	57.602	58.978	60.366	61.766
0.7	63.177	64.6	66.034	67.48	68.936	70.405	71.884	73.375	74.876	76.389
0.8	77.912	79.447	80.992	82.548	84.115	85.693	87.281	88.879	90.488	92.108
0.9	93.738	95.378	97.029	98.69	100.361	102.043	103.734	105.435	107.147	108.869
1	110.6	112.341	114.093	115.854	117.624	119.405	121.195	122.995	124.805	126.624
1.1	128.452	130.29	132.138	133.995	135.861	137.737	139.622	141.516	143.42	145.333
1.2	147.255	149.186	151.126	153.076	155.034	157.002	158.978	160.963	162.958	164.961
1.3	166.973	168.994	171.024	173.062	175.109	177.165	179.23	181.304	183.386	185.476
1.4	187.576	189.683	191.8	193.925	196.058	198.2	200.35	202.509	204.676	206.851
1.5	209.035	211.227	213.427	215.636	217.853	220.078	222.311	224.552	226.802	229.06
1.6	231.325	233.599	235.881	238.171	240.469	242.776	245.09	247.412	249.741	252.079
1.7	254.425	256.779	259.14	261.51	263.887	266.272	268.664	271.065	273.473	275.889
1.8	278.313	280.744	283.183	285.63	288.084	290.546	293.015	295.492	297.977	300.469
1.9	302.969	305.476	307.991	310.513	313.043	315.58	318.125	320.676	323.236	325.803

Table B.16 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2	328.377	330.958	333.547	336.143	338.746	341.357	343.975	346.6	349.232	351.872
2.1	354.519	357.173	359.834	362.503	365.178	367.861	370.551	373.248	375.951	378.663
2.2	381.381	384.106	386.838	389.577	392.324	395.077	397.837	400.604	403.379	406.16
2.3	408.948	411.743	414.545	417.353	420.169	422.992	425.821	428.657	431.5	434.35
2.4	437.207	440.07	442.94	445.817	448.701	451.592	454.489	457.393	460.303	463.221
2.5	466.145	469.076	472.013	474.957	477.908	480.865	483.829	486.8	489.777	492.76
2.6	495.751	498.747	501.751	504.761	507.777	510.8	513.83	516.866	519.908	522.957
2.7	526.013	529.075	532.777	536.466	540.166	543.878	547.602	551.338	555.086	558.846
2.8	562.617	566.401	570.196	574.003	577.823	581.654	585.496	589.351	593.217	597.096
2.9	600.986	604.888	608.802	612.727	616.665	620.614	624.575	628.548	632.532	636.529
3	640.537	644.557	648.588	652.632	656.687	660.754	664.833	668.923	673.025	677.139
3.1	681.265	685.402	689.551	693.712	697.885	702.069	706.265	710.473	714.692	718.923
3.2	723.166	727.42	731.687	735.964	740.254	744.555	748.868	753.192	757.528	761.876
3.3	766.235	770.606	774.989	779.383	783.789	788.207	792.636	797.077	801.529	805.993
3.4	810.469	814.956	819.455	823.965	828.487	833.021	837.566	842.123	846.691	851.271
3.5	855.862	860.465	865.08	869.706	874.344	878.993	883.654	888.326	893.01	897.705
3.7	950.113	954.946	959.791	964.647	969.515	974.394	979.285	984.187	989.101	994.026
3.8	998.963	1003.91	1008.87	1013.841	1018.823	1023.817	1028.822	1033.838	1038.866	1043.906

Table B.16 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
3.9	1048.957	1054.019	1059.092	1064.177	1069.274	1074.382	1079.501	1084.631	1089.773	1094.927
4	1100.092	1105.268	1110.455	1115.654	1120.864	1126.086	1131.319	1136.563	1141.819	1147.086
4.1	1152.364	1157.654	1162.955	1168.267	1173.591	1178.926	1184.272	1189.63	1194.999	1200.379
4.2	1205.771	1211.174	1216.588	1222.013	1227.45	1232.898	1238.358	1243.828	1249.31	1254.804
4.3	1260.308	1265.824	1271.351	1276.889	1282.439	1288	1293.572	1299.155	1304.75	1310.75
4.4	1315.973	1321.602	1327.241	1332.892	1338.554	1344.228	1349.912	1355.608	1361.315	1367.033
4.5	1372.763									

Table B.17 Expanded rating table for Whiteoak Creek Headwaters station located in the upper reaches of Whiteoak Creek and upstream of ORNL facility discharges

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	0.001	0.002	0.004	0.007	0.011	0.015	0.021	0.027	0.034
0.1	0.041	0.049	0.057	0.067	0.077	0.088	0.099	0.111	0.123	0.137
0.2	0.151	0.166	0.1182	0.1197	0.213	0.231	0.249	0.267	0.286	0.306
0.3	0.327	0.347	0.368	0.391	0.414	0.437	0.46	0.425	0.55	0.575
0.4	0.561	0.589	0.617	0.645	0.673	0.701	0.732	0.763	0.794	0.825
0.5	0.856	0.891	0.927	0.962	0.997	0.032	0.068	0.103	0.138	0.174
0.6	1.209	1.25	1.291	1.332	1.373	1.414	1.455	1.496	1.537	1.578
0.7	1.619	1.666	1.712	1.759	1.805	1.852	1.898	1.945	1.991	2.038
0.8	2.084	2.136	2.188	2.24	2.292	2.345	2.4	2.449	2.501	2.553
0.9	2.605	2.663	2.72	2.778	2.835	2.893	2.95	3.008	3.065	3.123
1	3.18	3.264	3.348	3.432	3.516	3.6	3.684	3.768	3.852	3.936
1.1	4.02	4.116	4.212	4.308	4.404	4.5	4.596	4.692	4.788	4.884
1.2	4.98	5.105	5.23	5.355	5.48	5.605	5.73	5.855	5.98	6.105
1.3	6.23	6.355	6.48	6.605	6.73	6.855	6.98	7.105	7.23	7.355
1.4	7.48	7.605	7.73	7.855	7.98	8.105	8.23	8.355	8.48	8.605
1.5	8.73	8.867	9.004	9.141	9.278	9.415	9.552	9.689	9.826	9.963
1.6	10.1	10.26	10.42	10.58	10.74	10.9	11.06	11.22	11.38	11.38

Table B.17 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1.7	11.7	11.92	12.14	12.36	12.58	12.8	13.02	13.24	13.46	13.68
1.8	13.9	14.21	14.52	14.83	15.14	15.45	15.76	16.07	16.38	16.69
1.9	17	17.4	17.8	18.2	18.6	19	19.4	19.8	20.2	20.6
2	21	21.4	21.8	22.2	22.6	23	23.4	23.8	24.2	24.6
2.1	25	25.5	26	26.5	27	27.5	28	28.5	29	29.5
2.2	30	30.6	31.2	31.8	32.4	33	33.6	34.2	34.8	35.4
2.3	36	36.7	37.4	38.1	38.8	39.5	40.2	40.9	40.6	41.3
2.4	43	43.8	44.6	45.4	46.2	47	47.8	48.6	49.4	50.2
2.5	51									

Table B.18 Expanded rating table for low flow at Whiteoak Creek station

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.2	0.111	0.125	0.141	0.157	0.175	0.194	0.214	0.235	0.257	0.281
0.3	0.305	0.331	0.359	0.387	0.417	0.448	0.481	0.515	0.55	0.587
0.4	0.626	0.665	0.706	0.749	0.793	0.839	0.886	0.935	0.985	1.037
0.5	1.091	1.146	1.203	1.262	1.322	1.384	1.447	1.513	1.58	1.648
0.6	1.719	1.791	1.865	1.941	2.019	2.098	2.18	2.263	2.348	2.435
0.7	2.524	2.615	2.708	2.803	2.899	2.998	3.099	3.201	3.306	3.413
0.8	3.521	3.632	3.745	3.86	3.977	4.096	4.217	4.34	4.466	4.593
0.9	4.723	4.855	4.989	5.126	5.264	5.405	5.548	5.693	5.84	5.99
1	6.142	6.296	6.453	6.612	6.773	6.936	7.102	7.27	7.441	7.614
1.1	7.789	7.967	8.147	8.33	8.515	8.702	8.892	9.084	9.279	9.477
1.2	9.676	9.879	10.083	10.291	10.501	10.713	10.928	11.145	11.365	11.588
1.3	11.813	12.041	12.272	12.505	12.74	12.979	13.22	13.463	13.71	13.959
1.4	14.21	14.465	14.722	14.982	15.244	15.51	15.778	16.048	16.322	16.598
1.5	16.877	17.159	17.444	17.732	18.022	18.315	18.611	18.91	19.212	19.516
1.6	19.824	20.134	20.447	20.763	21.082	21.404	21.729	22.057	22.388	22.721
1.7	23.058	23.397	23.74	24.086	24.434	24.786	25.14	25.498	25.859	26.222
1.8	26.589	26.959	27.332	27.708	28.087	28.469	28.854	29.242	29.634	30.028

Table B.18 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1.9	30.426	30.827	31.231	31.638	32.048	32.461	32.878	33.298	33.721	34.147
2	34.576	35.009	35.445	35.884	36.326	36.772	37.22	37.672	38.128	38.586
2.1	39.048	39.514	39.982	40.454	40.929	41.407	41.889	42.374	42.863	43.355
2.2	43.85	44.349	44.851	45.356	45.865	46.377	46.892	47.411	47.934	48.46
2.3	48.989	49.522	50.058	50.597	51.14	51.687	52.237	52.791	53.348	53.908
2.4	54.472	55.04	55.611	56.186	56.764	57.346	57.931	58.52	59.112	59.708
2.5	60.308									

Table B.19 Expanded rating table for high flow at Whiteoak Dam (WOD) station

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.2	0.09	0.102	0.116	0.13	0.145	0.162	0.179	0.198	0.218	0.239
0.3	0.261	0.285	0.31	0.336	0.363	0.392	0.422	0.454	0.487	0.521
0.4	0.557	0.594	0.633	0.674	0.716	0.759	0.804	0.851	0.9	0.95
0.5	1.002	1.055	1.11	1.167	1.226	1.287	1.349	1.414	1.48	1.548
0.6	1.618	1.69	1.764	1.839	1.917	1.997	2.079	2.163	2.248	2.336
0.7	2.427	2.519	2.613	2.71	2.808	2.909	3.013	3.118	3.226	3.335
0.8	3.448	3.562	3.679	3.798	3.92	4.044	4.17	4.299	4.43	4.563
0.9	4.699	4.838	4.979	5.123	5.269	5.418	5.569	5.723	5.879	6.038
1	6.2	6.364	6.531	6.701	6.874	7.049	7.227	7.407	7.591	7.777
1.1	7.966	8.158	8.353	8.55	8.751	8.954	9.16	9.37	9.582	9.797
1.2	10.015	10.236	10.46	10.687	10.917	11.15	11.386	11.625	11.867	12.113
1.3	12.361	12.613	12.868	13.126	13.387	13.651	13.919	14.189	14.464	14.741
1.4	15.021	15.305	15.592	15.883	16.177	16.474	16.774	17.078	17.385	17.696
1.5	18.01	18.327	18.648	18.973	19.301	19.632	19.967	20.305	20.647	20.993
1.6	21.342	21.694	22.05	22.41	22.774	23.141	23.511	23.886	24.264	24.645
1.7	25.031	25.42	25.813	26.209	26.609	27.014	27.421	27.833	28.249	28.668
1.8	29.091	29.518	29.949	30.384	30.822	31.265	31.711	32.161	32.616	33.074
1.9	33.536	34.002	34.473	34.947	35.425	35.907	36.394	36.884	37.378	37.877
2	38.38	38.886	39.397	39.912	40.431	40.955	41.482	42.014	42.55	43.09
2.1	43.634	44.183	44.736	45.293	45.854	46.42	46.99	47.564	48.143	48.726

Table B.19 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2.2	49.313	49.905	50.501	51.101	51.706	52.316	52.929	53.548	54.17	54.797
2.3	55.429	56.065	56.705	57.351	58	58.654	59.313	59.976	60.644	61.317
2.4	61.994	62.675	63.362	64.053	64.748	65.448	66.153	66.863	67.577	68.296
2.5	69.02	69.748	70.481	71.219	71.962	72.71	73.462	74.219	74.981	75.748
2.6	76.519	77.296	78.077	78.863	79.654	80.45	81.251	82.057	82.868	83.684
2.7	84.504	85.33	86.16	86.996	87.837	88.682	89.533	90.389	91.249	92.115
2.8	92.986	93.862	94.743	95.629	96.52	97.417	98.318	99.225	100.137	101.054
2.9	101.976	102.904	103.836	104.774	105.717	106.665	107.619	108.578	109.542	110.511
3	111.486	112.466	113.451	114.442	115.438	116.439	117.446	118.458	119.476	120.499
3.1	121.527	122.561	123.6	124.645	125.695	126.75	127.811	128.878	129.95	131.027
3.2	132.11	133.199	134.293	135.392	136.498	137.608	138.725	139.847	140.974	142.107
3.3	143.246	144.391	145.541	146.697	147.858	149.025	150.198	151.376	152.561	153.751
3.4	154.946	156.148	157.355	158.568	159.787	161.011	162.241	163.478	164.72	165.967
3.5	167.221	168.48	169.746	171.017	172.294	173.577	174.866	176.161	177.461	178.768
3.6	180.081	181.399	182.724	184.054	185.391	186.733	188.082	189.436	190.797	192.164
3.7	193.536	194.915	196.3	197.691	199.088	200.491	201.9	203.315	204.736	206.164
3.8	207.598	209.038	210.484	211.936	213.394	214.859	216.33	217.807	219.29	220.78
3.9	222.276	223.778	225.286	226.801	228.321	229.849	231.382	232.922	234.468	236.021
4	237.58	239.145	240.717	242.295	243.879	245.47	247.067	248.671	250.281	251.898

Table B.19 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
4.1	253.521	255.15	256.786	258.428	260.077	261.733	263.395	265.063	266.738	268.42
4.2	270.108	271.803	273.504	275.212	276.926	278.647	280.375	282.109	283.85	285.597
4.3	287.352	289.113	290.88	292.654	294.435	296.223	298.017	299.818	301.626	303.44
4.4	305.262	307.09	308.924	310.766	312.614	314.469	316.331	318.2	320.076	321.958
4.5	323.848	325.744	327.647	329.557	331.473	333.397	335.328	337.265	339.209	341.161
4.6	343.119	345.084	347.056	349.036	351.022	353.015	355.015	357.022	359.036	361.057
4.7	363.086	365.121	367.163	369.213	371.269	373.333	375.403	377.481	379.566	381.658
4.8	383.757	385.863	387.976	390.097	392.225	394.36	396.502	398.651	400.807	402.971
4.9	405.142	407.32	409.506	411.698	413.898	416.105	418.32	420.542	422.771	425.007
5	427.251	429.502	431.76	434.026	436.299	438.579	440.867	443.162	445.465	447.775
5.1	450.092	452.417	454.749	457.089	459.436	461.79	464.152	466.522	468.899	471.283
5.2	473.675	476.074	478.481	480.896	483.318	485.748	488.185	490.629	493.082	495.542
5.3	498.009	500.484	502.967	505.457	507.955	510.46	512.974	515.495	518.023	520.559
5.4	523.103	525.655	528.214	530.781	533.356	535.938	538.528	541.126	543.732	546.345
5.5	548.966	551.595	554.232	556.876	559.529	562.189	564.857	567.533	570.216	572.908
5.6	575.607	578.314	581.03	583.753	586.483	589.222	591.969	594.724	597.486	600.257
5.7	603.035	605.821	608.616	611.418	614.229	617.047	619.873	622.707	625.55	628.4
5.8	631.259	634.125	637	639.882	642.773	645.672	648.578	651.493	654.416	657.347
5.9	660.287	663.234	666.189	669.153	672.125	675.105	678.093	681.089	684.094	687.107

Table B.19 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
6	690.128	693.157	696.194	699.24	702.294	705.356	708.426	711.505	714.592	717.687
6.1	720.791	723.902	727.023	730.151	733.288	736.433	739.586	742.748	745.919	749.097
6.2	752.284	755.479	758.683	761.895	765.116	768.345	771.582	774.828	778.082	781.345
6.3	784.616	787.896	791.184	794.481	797.786	801.1	804.422	807.753	811.092	814.44
6.4	817.796	821.161	824.534	827.917	831.307	834.706	838.114	841.531	844.956	848.389
6.5	851.832	855.283	858.742	862.211	865.688	869.173	872.667	876.17	879.682	883.203
6.6	886.732	890.27	893.816	897.371	900.936	904.508	908.09	911.68	915.28	918.888
6.7	922.504	926.13	929.764	933.408	937.06	940.721	944.39	948.069	951.756	955.453
6.8	959.158	962.872	966.595	970.327	974.068	977.818	981.576	985.344	989.121	992.906
6.9	996.701	1000.504	1004.317	1008.138	1011.969	1015.808	1019.657	1023.514	1027.381	1031.256
7	1035.141	1039.035	1042.938	1046.849	1050.77	1054.7	1058.639	1062.588	1066.545	1070.511
7.1	1074.487	1078.472	1082.466	1086.469	1090.481	1094.502	1098.533	1102.572	1106.621	1110.679
7.2	1114.747	1118.823	1122.909	1127.004	1131.108	1135.222	1139.344	1143.476	1147.618	1151.768
7.3	1155.928	1160.097	1164.276	1168.463	1172.661	1176.867	1181.083	1185.308	1189.542	1193.786
7.4	1198.039	1202.302	1206.574	1210.855	1215.146	1219.446	223.756	1228.075	1232.403	1236.741
7.5	1241.089	1245.445	1249.812	1254.188	1258.573	1262.967	1267.372	1271.785	1276.209	1280.641
7.6	1285.084	1289.536	1293.997	1298.468	1302.948	1307.438	1311.938	1316.447	1320.966	1325.495
7.7	1330.033	1334.58	1339.138	1343.704	1348.281	1352.867	1357.463	1362.069	1366.684	1371.309
7.8	1375.943	1380.587	1385.241	1389.905	1394.578	1399.262	1403.954	1408.657	1413.369	1418.091

Table B.19 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
7.9	1422.823	1427.565	1432.316	1437.077	1441.848	1446.629	1451.42	1456.22	1461.031	1465.851
8	1470.681	1475.52	1480.37	1485.23	1490.099	1494.978	1499.867	1504.766	1509.675	1514.594
8.1	1519.523	1524.462	1529.41	1534.369	1539.338	1544.316	1549.305	1554.303	1559.311	1564.33
8.2	1569.358	1574.397	1579.445	1584.504	1589.572	1594.651	1599.739	1604.838	1609.947	1615.065
8.3	1620.194	1625.333	1630.482	1635.641	1640.81	1645.99	1651.179	1656.379	1661.588	1666.808
8.4	1672.038	1677.278	1682.529	1687.789	1693.06	1698.341	1703.632	1708.933	1714.245	1719.566
8.5	1724.898	1730.24	1735.593	1740.955	1746.328	1751.711	1757.105	1762.509	1767.923	1773.347
8.6	1778.782	1784.226	1789.682	1795.147	1800.623	1806.109	1811.606	1817.113	1822.63	1828.158
8.7	1833.696	1839.244	1844.803	1850.372	1855.952	1861.542	1867.143	1872.754	1878.375	1884.007
8.8	1889.649	1895.302	1900.965	1906.638	1912.323	1918.017	1923.722	1929.438	1935.164	1940.901
8.9	1946.648	1952.406	1958.174	1963.953	1969.742	1975.542	1981.353	1987.174	1993.005	1998.848
9	2004.7									

Table B.20 Expanded rating table for low flow at Whiteoak Dam (WOD) station

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.2	0.979	1.05	1.122	1.195	1.27	1.346	1.424	1.503	1.583	1.664
0.3	1.747	1.83	1.915	2.001	2.088	2.177	2.266	2.356	2.448	2.54
0.4	2.634	2.729	2.824	2.921	3.018	3.116	3.216	3.316	3.417	3.519
0.5	3.622	3.726	3.831	3.937	4.043	4.151	4.259	4.368	4.478	4.588
0.6	4.7	4.812	4.925	5.039	5.153	5.269	5.385	5.502	5.619	5.738
0.7	5.857	5.977	6.097	6.219	6.341	6.463	6.587	6.711	6.836	6.961
0.8	7.087	7.214	7.342	7.47	7.599	7.728	7.858	7.989	8.121	8.253
0.9	8.386	8.519	8.653	8.787	8.923	9.059	9.195	9.332	9.47	9.608
1	9.747	9.886	10.027	10.167	10.308	10.45	10.593	10.736	10.879	11.023
1.1	11.168	11.313	11.459	11.606	11.753	11.9	12.048	12.197	12.346	12.495
1.2	12.646	12.796	12.948	13.1	13.252	13.405	13.558	13.712	13.866	14.021
1.3	14.177	14.333	14.489	14.646						

Table B.21 Expanded rating table for Whiteoak Creek Parshall Flume station (GS5, USGS 03536380)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	0.04	0.08	0.123						
0.1	0.18	0.227	0.28	0.34	0.406	0.48	0.544	0.612	0.684	0.76
0.2	0.84	0.923	1.009	1.099	1.193	1.29	1.383	1.478	1.576	1.677
0.3	1.78	1.882	1.987	2.095	2.204	2.316	2.43	2.544	2.659	2.777
0.4	2.897	3.018	3.142	3.268	3.396	3.525	3.657	3.79	3.926	4.063
0.5	4.202	4.343	4.486	4.631	4.777	4.926	5.076	5.228	5.382	5.537
0.6	5.695	5.854	6.015	6.177	6.342	6.508	6.676	6.845	7.016	7.189
0.7	7.364	7.54	7.718	7.897	8.079	8.261	8.446	8.632	8.82	9
0.8	9.2	9.379	9.56	9.742	9.925	10.109	10.295	10.481	10.669	10.858
0.9	11.049	11.24	11.433	11.627	11.821	12.018	12.215	12.413	12.613	12.813
1	13.015	13.218	13.422	13.627	13.833	14.041	14.249	14.459	14.669	14.881
1.1	15.094	15.308	15.523	15.739	15.956	16.174	16.393	16.613	16.835	17.057
1.2	17.28	17.505	17.73	17.956	18.184	18.412	18.642	18.872	19.104	19.337
1.3	19.57	19.805	20.04	20.277	20.514	20.753	20.992	21.233	21.474	21.716
1.4	21.96	22.204	22.449	22.696	22.943	23.191	23.44	23.69	23.941	24.193
1.5	24.446	24.7	24.955	25.21	25.467	25.725	25.983	26.243	26.503	26.764
1.6	27.026	27.289	27.553	27.818	28.084	28.351	28.618	28.887	29.156	29.426

Table B.21 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1.7	29.697	29.969	30.242	30.516	30.791	31.066	31.343	31.62	31.898	32.177
1.8	32.457	32.738	33.02	33.302	33.585	33.87	34.155	34.44	34.727	35.015
1.9	35.303	35.593	35.883	36.174	36.465	36.758	37.052	37.346	37.641	37.937
2	38.234	38.531	38.83	39.129	39.429	39.73	40.032	40.334	40.638	40.942
2.1	41.247	41.552	41.859	42.166	42.475	42.784	43.093	43.404	43.715	44.027
2.2	44.34	44.654	44.969	45.284	45.6	45.928	46.258	46.588	46.919	47.251
2.3	47.583	47.917	48.252	48.587	48.923	49.261	49.599	49.938	50.277	50.618
2.4	50.96	51.302	51.645	51.99	52.335	52.681	53.027	53.375	53.724	54.073
2.5	54.423	54.774	55.126	55.479	55.832	56.187	56.542	56.898	57.255	57.613
2.6	57.972	58.332	58.692	59.053	59.415	59.778	60.142	60.507	60.872	61.238
2.7	61.606	61.973	62.342	62.712	63.082	63.453	63.826	64.198	64.572	64.947
2.8	65.322	65.698	66.075	66.453	66.832	67.211	67.591	67.972	68.354	68.737
2.9	69.121	69.505	69.89	70.276	70.663	71.05	71.438	71.828	72.218	72.608
3	73	73.489	73.979	74.472	74.965	75.461	75.958	76.457	76.957	77.459
3.1	77.963	78.468	78.975	79.484	79.994	80.506	81.019	81.534	82.051	82.57
3.2	83.09	83.611	84.135	84.66	85.186	85.714	86.244	86.776	87.309	87.844
3.3	88.38	88.918	89.458	89.999	90.542	91.087	91.633	92.181	92.73	93.281

Table B.21 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
3.4	93.834	94.389	94.945	95.502	96.062	96.623	97.185	97.75	98.315	98.883
3.5	99.452	100.023	100.595	101.17	101.745	102.323	102.902	103.482	104.064	104.648
3.6	105.234	105.821	106.41	107	107.593	108.186	108.782	109.379	109.977	110.576
3.7	111.18	111.783	112.388	112.995	113.604	114.214	114.826	115.439	116.054	116.671
3.8	117.289	117.909	118.531	119.154	119.779	120.405	121.033	121.663	122.295	122.928
3.9	123.563	124.199	124.837	125.477	126.118	126.761	127.405	128.051	128.699	129.349
4	130	130.624	131.25	131.878	132.507	133.137	133.769	134.402	135.036	135.672
4.1	136.31	136.949	137.589	138.23	138.874	139.518	140.164	140.812	141.461	142.111
4.2	142.763	143.416	144.07	144.726	145.384	146.043	146.703	147.365	148.028	148.692
4.3	149.358	150.026	150.695	151.365	152.037	152.71	153.384	154.06	154.738	155.416
4.4	156.097	156.778	157.461	158.146	158.832	159.519	160.208	160.898	161.59	162.283
4.5	162.977	163.673	164.37	165.069	165.769	166.471	167.174	167.878	168.584	169.291
4.6	170	170.83	171.664	172.499	173.337	174.177	175.019	175.863	176.71	177.559
4.7	178.41	179.263	180.119	180.977	181.837	182.699	183.564	184.431	185.301	186.172
4.8	187.046	187.922	188.8	189.681	190.564	191.449	192.336	193.226	194.118	195.012
4.9	195.909	196.808	197.709	198.612	199.518	200.426	201.336	202.248	203.163	204.08
5	205	205.767	206.536	207.306	208.078	208.85	209.624	210.4	211.177	211.955

Table B.21 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
5.1	212.734	213.515	214.297	215.081	215.865	216.652	217.439	218.228	219.018	219.809
5.2	220.602	221.396	222.191	222.988	223.786	224.585	225.386	226.188	226.991	227.796
5.3	228.602	229.41	230.218	231.028	231.839	232.652	233.466	234.281	235.098	235.916
5.4	236.735	237.555	238.377	239.201	240.025	240.851	241.678	242.507	243.336	244.167
5.5	245									

Offset=0.00

Table B.22 Expanded rating table for West Seep Tributary station

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0					0.003	0.005	0.007	0.008	0.009	0.012
0.1	0.016	0.02	0.025	0.03	0.036	0.043	0.05	0.058	0.066	0.075
0.2	0.085	0.096	0.108	0.12	0.133	0.147	0.162	0.178	0.195	0.212
0.3	0.23	0.25	0.27	0.291	0.313	0.336	0.359	0.385	0.411	0.438
0.4	0.466	0.495	0.525	0.556	0.588	0.621	0.655	0.691	0.727	0.765
0.5	0.803	0.843	0.884	0.927	0.97	1.015	1.06	1.107	1.155	1.205
0.6	1.255	1.307	1.36	1.415	1.47	1.527	1.585	1.645	1.705	1.767
0.7	1.83	1.895	1.96	2.028	2.096	2.166	2.237	2.31	2.384	2.46
0.8	2.537	2.615	2.694	2.776	2.858	2.942	3.027	3.114	3.202	3.292
0.9	3.383	3.476	3.57	3.666	3.763	3.862	3.962	4.064	4.167	4.272
1	4.378	4.488	4.599	4.709	4.819	4.93	5.046	5.163	5.279	5.396
1.1	5.512	5.634	5.755	5.877	5.998	6.12	6.247	6.373	6.5	6.626
1.2	6.753	6.886	7.02	7.153	7.287	7.42	7.553	7.687	7.82	7.954
1.3	8.087	8.229	8.371	8.512	8.654	8.796	8.938	9.08	9.221	9.363
1.4	9.505	9.655	9.804	9.954	10.103	10.253	10.402	10.552	10.701	10.851
1.5	11	11.157	11.313	11.47	11.626	11.783	11.94	12.096	12.253	12.409
1.6	12.566	12.733	12.899	13.066	13.233	13.4	13.566	13.733	13.9	14.066

Table B.22 (continued)

INPUT VALUE	GAGE HEIGHT									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1.7	14.233	14.4	14.566	14.733	14.9	15.067	15.233	15.4	15.567	15.733
1.8	15.9	16.079	16.258	16.437	16.616	16.795	16.973	17.152	17.331	17.51
1.9	17.689	17.868	18.047	18.226	18.405	18.584	18.762	18.941	19.12	19.299
2	19.478	19.668	19.858	20.048	20.239	20.429	20.619	20.809	20.999	21.189
2.1	21.38	21.57	21.76	21.95	22.14	22.33	22.52	22.711	22.901	23.091
2.2	23.281	23.482	23.682	23.883	24.083	24.284	24.484	24.685	24.885	25.086
2.3	25.287	25.487	25.688	25.888	26.089	26.289	26.49	26.69	26.891	27.091
2.4	27.292	27.502	27.713	27.923	28.134	28.344	28.554	28.765	28.975	29.186
2.5	29.396	29.606	29.817	30.027	30.238	30.448	30.658	30.869	31.079	31.29
2.6	31.5	31.717	31.933	32.15	32.367	32.584	32.8	33.017		

APPENDIX C

Daily Streamflow for Monitoring Stations in Whiteoak Creek Watershed

Table C.1. Daily stream flows for Melton Branch (station MS4) for Water Year 1990
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	33 (e)	0.659	2.173	6.938	3.311	1.811	1.298	31.136	1.458	3.470	0.805	1.076
2	7.823	0.582	1.819	3.625	2.903	6.032	1.227	10.592	1.357	2.429	0.822	1.054
3	3.728	0.545	1.559	2.595	39 (e)	5.756	1.150	5.715	1.456	0.929	0.847	0.999
4	2.473	0.506	1.411	5.592	33 (e)	3.470	1.094	27.680	1.284	0.729	1.144	1.037
5	1.754	0.500	1.331	4.876	8.302	2.630	1.027	9.258	1.214	0.682	3.481	0.977
6	1.469	5.047	1.365	5.683	4.816	2.188	2.999	4.701	1.422	0.763	2.129	0.950
7	1.202	6.508	1.154	4.544	4.177	1.869	2.889	3.218	1.379	0.726	1.092	0.978
8	1.056	8.203	3.161	11.969	3.070	2.076	1.763	2.399	1.318	0.696	1.713	0.687
9	0.979	5.442	2.086	6.463	4.070	2.329	1.468	4.057	2.556	0.681	6.160	0.641
10	1.047	2.819	1.611	4.085	36 (e)	3.861	1.868	6.381	2.394	0.691	4.622	0.729
11	0.787	1.898	1.486	2.995	8.302	3.447	1.716	3.337	1.377	1.233	1.648	0.776
12	0.687	1.479	1.892	2.407	4.846	2.663	1.293	2.670	1.163	8.097	1.154	0.839
13	0.640	1.243	1.546	2.004	3.586	2.252	1.174	1.950	1.087	5.967	0.977	0.974
14	0.631	1.636	1.433	1.791	2.876	1.995	1.291	1.685	1.130	14.694	2.027	1.016
15	0.521	10 (e)	1.358	1.711	3.075	1.858	1.524	1.471	1.108	2.460	1.667	2.121
16	1.225	21 (e)	1.107	1.413	44.076	31.053	1.166	1.301	0.926	1.258	1.4 (e)	0.846
17	3.830	4.713	1.020	1.359	9.750	40.920	1.346	4.166	0.831	1.066	1.6 (e)	0.675
18	1.991	2.940	1.030	8.667	5.735	8.599	1.286	1.584	0.847	0.919	1.3 (e)	0.636
19	2.392	2.190	1.543	4.003	8.493	5.457	1.060	1.298	0.857	0.893	1.2 (e)	0.715

Table C.1 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	1.342	1.818	1.400	21 (e)	5.328	3.903	0.999	1.858	0.904	0.997	1.2 (e)	0.806
21	1.017	1.527	1.021	13.231	3.881	2.992	4.046	1.725	0.975	2.449	1.2 (e)	0.799
22	0.858	5.311	0.734	5.523	5.535	2.508	4.600	1.564	1.236	3.346	4.0 (e)	0.951
23	0.763	6.173	0.599	3.672	4.217	2.169	2.337	1.339	0.871	2.057	2.1 (e)	0.792
24	0.718	3.211	0.576	3.992	3.105	1.926	1.669	1.200	0.816	1.194	1.7 (e)	0.851
25	0.661	2.374	0.799	6.582	2.481	1.697	1.403	1.089	0.755	0.910	1.438	0.894
26	0.627	2.002	1.039	4.327	2.159	1.481	1.367	1.094	0.831	0.869	1.379	1.025
27	0.705	2.090	0.977	3.012	1.937	1.295	1.223	4.160	0.646	0.939	1.256	1.332
28	0.559	9.426	0.871	2.450	1.808	1.255	2.726	9.936	0.822	0.879	1.136	0.843
29	0.531	4.340	0.852	26 (e)		1.475	1.880	4.377	0.879	0.860	1.668	0.869
30	0.524	2.806	2.455	9.201		1.593	1.386	2.097	0.647	0.850	1.432	0.876
31	0.739		26 (e)	4.762		1.473		1.679		0.833	1.168	

(e) - Estimated value. These data are one significant figure lesss than the calculated value from station data.

Table C.2. Daily stream flows for Whiteoak Creek (station MS3) for Water Year 1990
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	89.950	6.074	11.672	26.243	15.854	10.324	8.122	62.676	8.429	18.923	1.076	6.416
2	32.730	6.351	10.733	17.957	14.023	19.112	7.936	27.521	7.779	12.832	6.061	6.165
3	23 (e)	6.068	9.341	14.456	79.610	15.916	7.854	20.115	8.122	7.133	5.946	6.373
4	16 (e)	6.033	8.824	20.866	85.339	13.282	7.799	57.458	7.308	6.501	6.935	6.017
5	13 (e)	6.007	8.657	17.091	32.326	12.106	7.480	34.186	6.890	6.249	18.910	5.904
6	11 (e)	15.453	8.261	18.681	22.177	11.439	11.424	20.952	6.831	6.117	11.859	5.679
7	10 (e)	18.505	8.085	16.775	18.178	10.539	9.455	16.102	6.935	6.134	8.187	5.929
8	9.2 (e)	24.224	12.113	30.622	14.809	10.793	8.251	13.230	6.847	5.837	8.877	5.890
9	8.0 (e)	17.774	9.079	22.947	16.393	10.725	7.952	16.649	14.638	5.883	31.198	5.826
10	7.8 (e)	13.051	8.239	17.897	85.875	14.729	9.464	18.441	11.721	6.010	22.319	5.884
11	7.3 (e)	11.243	8.070	14.944	31.538	11.756	8.565	12.678	8.349	8.810	11.437	5.869
12	7.0 (e)	10.083	9.203	13.076	21.080	11.284	7.644	11.468	7.367	28.076	9.139	6.495
13	7.0 (e)	8.850	8.462	11.372	16.633	10.663	7.298	10.239	6.756	20.131	8.190	6.465
14	6.7 (e)	9.734	7.929	10.511	14.148	10.311	7.994	9.658	6.654	37.099	12.623	6.152
15	6.5 (e)	42.216	8.143	10.086	14.352	9.794	7.736	8.941	6.151	13.126	10.377	10.711
16	11 (e)	54.117	7.781	9.7 (e)	90.408	60.829	7.584	8.462	5.980	10.159	8.539	5.873
17	14 (e)	22.549	7.441	9.6 (e)	34.283	96.966	8.525	16.971	5.784	8.875	9.801	5.608
18	10.043	15.733	7.634	26 (e)	23.498	33.316	7.767	9.389	6.229	7.665	7.768	5.541
19	10.077	12.587	8.761	16 (e)	25.953	22.860	7.270	8.259	5.979	7.520	7.245	6.160
20	8.150	11.612	7.909	40 (e)	19.697	17.419	7.492	8.999	6.036	7.363	7.158	6.294

Table C.2 (continued)

21	7.662	10.174	7.558	37 (e)	16.923	14.793	12.606	8.161	6.100	15.147	6.911	6.514
22	7.055	18.901	6.963	23 (e)	20.737	13.212	10.181	7.933	7.491	12.615	21.279	6.987
23	7.108	15.822	6.937	18 (e)	16.494	12.191	9.132	7.032	5.984	9.096	12.241	5.726
24	7.076	12.685	6.565	19 (e)	14.208	11.054	8.724	6.973	5.713	7.531	10.089	5.395
25	6.770	11.635	6.632	21 (e)	12.195	10.167	8.433	6.753	5.772	6.924	8.725	5.099
26	6.559	10.925	6.561	17 (e)	11.435	9.932	8.020	8.200	5.482	6.665	8.182	4.972
27	6.320	10.891	6.812	15 (e)	10.884	9.498	8.028	15.218	5.617	6.562	7.544	5.209
28	6.387	24.412	6.870	13 (e)	10.451	9.059	11.826	23.635	5.651	6.496	7.294	5.384
29	5.790	14.189	7.015	54 (e)		9.271	8.742	13.746	5.965	6.186	10.108	5.095
30	6.054	12.850	11.676	33 (e)		9.153	8.139	10.763	6.460	6.146	7.600	5.162
31	6.600		57.065	18.955		8.433		9.575		5.993	6.904	

(e) - Estimated value. These data are one significant figure lesss than the calculated value from station data.

Table C.3. Daily streamflows for Whiteoak Dam (MS5) monitoring station
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	174.732	7.103	124.437	38.190	20.536	12.949	9.614	91.424	10.198	8.017	5.241	6.406
2	45.297	6.812	13.079	20.49	17.449	20.504	8.948	59.188	8.966	27.44	5.343	6.176
3	24.376	6.623	11.39	15.521	104.435	25.236	8.611	22.651	9.248	9.083	5.26	6.249
4	16.734	6.592	10.372	20.988	161.382	17.312	8.501	89.069	8.606	6.761	5.331	6.239
5	14.132	6.579	10.191	21.139	48.626	14.541	8.257	49.043	7.607	6.02	16.554	6.228
6	12.727	14.009	9.791	22.366	29.456	13.7	11.009	26.026	7.491	5.674	17.53	6.219
7	11.243	21.592	9.379	19.992	23.21	13.517	14.145	18.735	7.514	5.851	8.923	6.212
8	10.018	34.286	13.823	38.031	18.29	13.336	10.698	14.533	7.545	5.579	8.72	6.041
9	8.791	28.395	12.556	31.691	17.127	14.074	9.484	21	12.735	5.604	15.802	5.809
10	7.553	17.824	10.674	22.284	129.017	15.102	10.061	25	18.286	5.679	43.75	5.730
11	6.782	14.063	9.825	17.446	48.912	14.844	11.475	16	11.292	6.192	14.335	5.739
12	7.456	12.96	10.975	14.827	28.447	14.036	9.321	14.198	8.715	30.651	9.732	5.931
13	7.84	11.259	10.426	13.985	21.101	13.829	8.607	12.48	7.826	27.756	8.058	6.582
14	7.302	11.553	9.654	12.634	17.178	12.928	8.588	11.456	7.670	60.709	9.846	6.414
15	6.832	28.358	9.419	11.911	15.828	12.25	10.047	10.519	7.588	19.023	16.173	2.609
16	9.006	96.382	9.071	11.107	142.178	69.281	8.864	10.003	6.988	11.219	10.323	7.087
17	17.548	33.309	8.71	10.705	56.87	173.936	9.255	20.11	6.469	8.583	9.589	5.898
18	13.192	21.083	8.869	30.084	30.725	49.842	9.96	13.076	6.532	7.346	9.82	5.727
19	14.202	15.774	10.268	20.642	35.131	29.177	8.568	10.115	6.658	6.815	7.841	6.002

Table C.3 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	11.048	13.468	10.25	47.741	26.81	21.602	8.47	10.427	6.451	7.250	7.345	6.589
21	9.573	13.917	9.126	63.164	21.064	17.392	11.023	10.824	6.640	11.135	7.006	6.572
22	8.619	18.477	8.252	31.165	24.381	14.854	16.429	9.79	7.873	19.113	16.559	7.768
23	8.124	27.904	7.531	21.744	22.163	14.463	12.793	8.903	7.250	12.923	15.769	6.472
24	7.932	17.236	7.561	19.222	17.178	13.802	11.083	8.419	6.319	9.017	10.763	5.939
25	7.727	14.01	7.883	27.479	14.123	12.538	10.316	8.017	6.125	7.474	9.055	5.805
26	7.433	13.545	8.095	21.608	13.421	11.434	9.743	7.966	6.169	6.824	8.164	5.676
27	7.105	14.293	8.27	16.899	13.565	10.699	9.571	14.301	6.050	6.587	7.484	6.059
28	7.084	31.859	8.42	14.54	13.332	10.259	12.002	33.097	6.197	6.610	7.121	6.113
29	6.548	21.722	8.348	71.511		10.558	12.811	24.007	6.483	6.242	8.424	5.794
30	6.447	16.015	11.712	52.317		10.824	10.174	13.974	6.703	5.798	10.176	5.623
31	7.461		81.945	27.716		10.522		12.101		5.377	7.072	

(e) - Estimated value. These data are one significant figure less than the calculated value from station data.

Table C.4 Daily streamflows for East Seep Tributary monitoring station
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	0.603	0.018	0.053	0.165	0.069	0.047	0.04 (e)	0.67 (e)	0.025	0.057	0.008	0.009
2	0.154	0.016	0.05	0.09	0.063	0.12	0.04 (e)	0.218	0.023	0.027	0.002	0.009
3	0.077	0.014	0.041	0.071	0.688	0.114	0.04 9e)	0.145	0.029	0.005	0.003	0.009
4	0.051	0.013	0.038	0.129	0.591	0.078	0.03 (e)	0.467	0.022	0.005	0.012	0.009
5	0.048	0.016	0.036	0.103	0.153	0.063	0.025	0.164	0.014	0.006	0.074	0.006
6	0.044	0.115	0.035	0.117	0.094	0.055	0.066	0.103	0.01	0.008	0.040	0.005
7	0.036	0.136	0.032	0.099	0.081	0.048	0.054	0.078	0.008	0.007	0.009	0.005
8	0.028	0.165	0.09	0.229	0.062	0.057	0.039	0.064	0.007	0.007	0.032	0.005
9	0.038	0.119	0.058	0.129	0.083	0.06	0.034	0.098	0.102	0.002	0.072	0.006
10	0.035	0.066	0.051	0.084	0.613	0.083	0.047	0.132	0.071	0.002	0.054	0.007
11	0.016	0.047	0.052	0.064	0.157	0.072	0.040	0.082	0.024	0.017	0.017	0.007
12	0.019	0.036	0.068	0.051	0.091	0.062	0.031	0.07 (e)	0.016	0.225	0.008	0.009
13	0.022	0.031	0.05	0.04	0.07	0.054	0.029	0.06 (e)	0.012	0.144	0.005	0.016
14	0.019	0.043	0.045	0.037	0.06	0.049	0.036	0.05 (e)	0.017	0.304	0.010	0.033
15	0.022	0.288	0.045	0.035	0.068	0.044	0.037	0.04 (e)	0.014	0.044	0.058	0.033
16	0.06	0.353	0.035	0.033	0.796	0.551	0.029	0.04 (e)	0.011	0.014	0.023	0.009
17	0.133	0.099	0.037	0.031	0.185	0.709	0.037	0.07 (e)	0.01	0.007	0.028	0.009
18	0.062	0.062	0.039	0.158	0.122	0.16	0.032	0.05 (e)	0.009	0.005	0.017	0.006
19	0.062	0.047	0.052	0.08	0.188	0.102	0.028	0.03 (e)	0.008	0.005	0.010	0.008

Table C.4 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.04	0.041	0.05 (e)	0.346	0.122	0.076	0.028	0.03 (e)	0.007	0.008	0.011	0.013
21	0.029	0.036	0.04 (e)	0.246	0.092	0.062	0.049	0.03 (e)	0.004	0.078	0.008	0.016
22	0.024	0.117	0.03 (e)	0.105	0.14	0.055	0.044	0.02 (e)	0.016	0.085	0.038	0.014
23	0.02	0.114	0.03 (e)	0.074	0.096	0.051	0.033	0.02 (e)	0.013	0.046	0.021	0.022
24	0.019	0.07	0.03 (e)	0.086	0.066	0.05	0.028	0.02 (e)	0.01	0.02	0.014	0.007
25	0.021	0.055	0.04 (e)	0.117	0.054	0.046	0.024	0.024	0.01	0.018	0.011	0.012
26	0.027	0.048	0.03 (e)	0.084	0.052	0.042	0.022	0.028	0.011	0.014	0.011	0.007
27	0.023	0.046	0.03 (e)	0.064	0.047	0.04	0.019	0.066	0.011	0.016	0.010	0.004
28	0.018	0.194	0.04 (e)	0.054	0.046	0.039	0.061	0.154	0.007	0.017	0.012	0.005
29	0.016	0.094	0.06 (e)	0.458		0.047	0.037	0.075	0.004	0.016	0.036	0.006
30	0.016	0.066	0.075	0.18		0.048	0.028	0.040	0.004	0.014	0.020	0.005
31	0.026		0.570	0.092		0.043		0.030		0.010	0.012	

(e) - Estimated value. These data are one significant figure less than the calculated value from station data.

Table C.5 Daily streamflows for West Seep Tributary monitoring station
units=cfs

DAY	OCT89	NOV 89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	4.706	0.068	0.414	1.437	1.221	0.785	0.24 (e)	6.948	0.383	0.329	0.022	0.037
2	0.887	0.066	0.32	0.702	1.058	1.013	0.22 (e)	2.159	0.155	0.188	0.024	0.032
3	0.354	0.06 (e)	0.253	0.484	7.615	1.112	0.20 (e)	1.187	0.173	0.046	0.023	0.035
4	0.224	0.06 (e)	0.23	0.987	6.459	0.707	0.18 (e)	4.894	0.132	0.033	0.098	0.028
5	0.178	0.06 (e)	0.216	0.950	1.628	0.563	0.171	1.619	0.112	0.028	0.569	0.026
6	0.158	0.30 (e)	0.199	1.091	0.832	0.509	0.416	0.848	0.103	0.028	0.293	0.024
7	0.147	0.48 (e)	0.183	0.934	0.685	0.469	0.425	0.536	0.097	0.024	0.098	0.023
8	0.147	0.90 (e)	0.466	2.259	0.522	0.452	0.325	0.366	0.093	0.017	0.202	0.022
9	0.147	0.80 (e)	0.346	1.322	0.675	0.457	0.280	0.589	0.765	0.017	0.424	0.021
10	0.363	0.55 (e)	0.3	0.748	7.469	0.607	0.343	1.076	0.567	0.016	0.358	0.020
11	0.658	0.421	0.279	0.536	1.512	0.595	0.309	0.596	0.207	0.151	0.148	0.020
12	0.569	0.314	0.325	0.399	0.816	0.518	0.247	0.54 (e)	0.126	1.538	0.095	0.025
13	0.514	0.263	0.271	0.314	0.577	0.476	0.225	0.47 (e)	0.106	0.903	0.062	0.035
14	0.123	0.320	0.244	0.278	0.467	0.444	0.245	0.34 (e)	0.115	2.515	0.813	0.032
15	0.108	2.929	0.238	0.254	0.501	0.408	0.273	0.26 (e)	0.098	0.353	0.258	0.287
16	0.177	4.263	0.23	0.230	7.813	5.701	0.222	0.22 (e)	0.078	0.141	0.120	0.040
17	0.608	1.027	0.23	0.230	1.732	7.354	0.249	0.30 (e)	0.058	0.086	0.187	0.029
18	0.269	0.587	0.23	1.438	0.962	1.459	0.238	0.40 (e)	0.058	0.066	0.074	0.027
19	0.316	0.419	0.268	0.787	1.398	0.898	0.207	0.172	0.055	0.057	0.057	0.028

Table C.5 (continued)

DAY	OCT89	NOV 89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.21	0.356	0.217	3.370	1.000	0.669	0.194	0.235	0.042	0.072	0.077	0.029
21	0.153	0.292	0.20 (e)	2.628	0.735	0.522	0.358	0.191	0.045	0.620	0.07 (e)	0.030
22	0.114	0.900	0.16 (e)	1.048	0.931	0.460	0.398	0.165	0.101	0.879	0.22 (e)	0.050
23	0.108	1.326	0.15 (e)	0.656	0.792	0.41	0.326	0.142	0.048	0.504	0.20 (e)	0.028
24	0.096	0.708	0.15 (e)	0.660	0.634	0.39	0.271	0.124	0.032	0.174	0.063	0.026
25	0.085	0.509	0.35 (e)	1.122	0.532	0.37	0.226	0.115	0.027	0.095	0.047	0.024
26	0.085	0.417	0.37 (e)	0.859	0.492	0.35	0.195	0.134	0.025	0.064	0.039	0.026
27	0.085	0.633	0.33 (e)	0.595	0.707	0.33	0.168	0.516	0.022	0.051	0.034	0.024
28	0.074	2.355	0.21 (e)	0.466	0.863	0.32	0.460	1.435	0.020	0.045	0.030	0.024
29	0.066	1.456	0.29 (e)	4.592		0.30	0.290	1.054	0.022	0.034	0.205	0.025
30	0.066	0.639	0.60 (e)	1.842		0.28	0.219	0.897	0.019	0.029	0.108	0.0245
31	0.076		5.548	1.270		0.26		0.718		0.029	0.049	

(e) - Estimated value. These data are one significant figure less than the calculated value from station data.

Table C.6 Daily streamflows at Whiteoak Creek Headwaters monitoring station
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	19.704	0.439	1.863	5.355	2.806	1.474	0.938	1.728	1.042	0.854	0.28 (e)	0.611
2	7.616	0.414	1.654	3.169	2.345	1.773	0.887	2.61	0.880	1.004	0.28 (e)	0.543
3	4.203	0.387	1.433	2.457	10.758	2.055	0.842	2.332	0.809	0.679	0.27 (e)	0.510
4	2.933	0.348	1.216	2.585	18.516	2.021	0.806	6.872	0.733	0.569	0.48 (e)	0.473
5	2.321	0.348	1.101	2.426	7.761	1.967	0.782	6.322	0.665	0.504	2.0 (e)	0.450
6	1.961	0.618	0.993	2.483	4.690	1.827	0.890	3.592	0.617	0.453	1.5 (e)	0.443
7	1.589	0.905	0.863	2.437	3.376	1.653	0.932	2.588	0.579	0.414	0.80 (e)	0.43 (e)
8	1.287	2.005	0.965	3.862	2.604	1.512	0.891	2.067	0.546	0.380	0.70 (e)	0.42 (e)
9	1.078	2.336	0.906	3.726	2.525	1.393	0.891	1.958	1.407	0.352	0.65 (e)	0.41 (e)
10	0.938	1.996	0.858	2.845	14.002	1.650	0.937	2.086	2.054	0.335	0.75 (e)	0.40 (e)
11	0.831	1.658	0.856	2.381	7.558	1.705	0.945	1.774	1.558	0.430	0.60 (e)	0.39 (e)
12	0.756	1.366	0.891	2.041	4.374	1.685	0.874	1.59	1.265	1.042	0.48 (e)	0.43 (e)
13	0.683	1.109	0.857	1.671	3.135	1.650	0.832	1.397	0.998	1.429	0.36 (e)	0.50 (e)
14	0.632	1.027	0.803	1.438	2.539	1.593	0.845	1.152	0.832	3.805	1.2 (e)	0.60 (e)
15	0.605	3.719	0.807	1.239	2.314	1.482	0.870	1.008	0.747	2.158	1.9 (e)	1.1 (e)
16	0.692	47.6	0.746	1.078	13.585	5.679	0.834	0.897	0.664	1.1 (e)	1.7 (e)	0.55 (e)
17	0.868	5.051	0.701	0.987	8.218	19.337	0.836	1.3	0.593	0.85 (e)	1.508	0. 40 (e)
18	0.83	3.09	0.678	2.069	4.966	8.093	0.790	1.088	0.552	0.66 (e)	1.224	0.347
19	0.924	2.318	0.704	2.079	4.405	4.803	0.752	0.961	0.516	0.58 (e)	1.001	0.353

Table C.6 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.86	2.009	0.671	4.466	3.395	3.234	0.732	0.91	0.494	.70 (e)	0.851	0.338
21	0.764	1.728	0.627	6.986	2.924	2.577	0.811	0.836	0.472	1.6 (e)	0.799	0.333
22	0.677	1.914	0.572	4.048	3.075	2.223	0.891	0.776	0.486	3.5 (e)	2.032	0.335
23	0.609	2.172	0.561	2.947	2.794	1.986	0.891	0.718	0.450	2.0 (e)	2.750	0.321
24	0.567	2.071	0.561	2.526	2.453	1.794	0.887	0.676	0.427	0.82 (e)	2.115	0.322
25	0.533	1.954	0.569	2.599	2.127	1.593	0.845	0.637	0.408	0.393	1.748	0.319
26	0.512	1.789	0.6	2.356	1.923	1.389	0.812	0.694	0.390	0.362	1.417	0.296
27	0.494	1.605	0.589	2.147	1.783	1.212	0.778	0.895	0.370	0.341	1.099	0.280
28	0.485	2.207	0.562	1.971	1.633	1.119	0.855	1.71	0.354	0.328	0.924	0.276
29	0.473	2.146	0.542	6.024		1.078	0.804	1.83	0.341	0.311	0.854	0.263
30	0.46	2.047	0.798	6.464		1.043	0.740	1.57	0.329	0.291	0.794	0.262
31	0.486		6.346	3.712		0.995		1.283		0.294	0.698	

(e) - Estimated value. These data are one significant figure less than the calcualted value from station data.

Table C.7. Daily streamflow at monitoring station GS16 (USGS 03537050) in Water Year 1990
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	5.20	0.07	0.26	1.00	0.38	0.21	0.15	5.00	0.06	0.32	0.00	0.01
2	0.98	0.06	0.21	0.46	0.34	1.00	0.13	1.40	0.05	0.16	0.00	0.01
3	0.39	0.05	0.17	0.31	7.20	0.94	0.12	1.00	0.08	0.02	0.00	0.01
4	0.21	0.05	0.16	0.90	4.90	0.49	0.11	5.00	0.05	0.01	0.01	0.01
5	0.14	0.05	0.14	0.84	0.89	0.32	0.10	1.20	0.03	0.01	0.20	0.01
6	0.11	0.86	0.13	1.40	0.52	0.26	0.53	0.52	0.02	0.01	0.13	0.01
7	0.07	1.10	0.11	1.20	0.48	0.22	0.44	0.30	0.02	0.01	0.03	0.00
8	0.06	1.30	0.46	2.40	0.32	0.27	0.25	0.19	0.02	0.01	0.04	0.00
9	0.05	0.70	0.28	0.91	0.57	0.30	0.20	0.51	0.19	0.00	1.10	0.00
10	0.05	0.40	0.21	0.50	6.10	0.77	0.30	0.90	0.16	0.00	0.55	0.00
11	0.05	0.20	0.19	0.34	1.00	0.58	0.26	0.34	0.07	0.01	0.10	0.00
12	0.04	0.14	0.26	0.25	0.52	0.37	0.19	0.22	0.04	0.96	0.05	0.00
13	0.04	0.12	0.20	0.20	0.36	0.29	0.16	0.15	0.02	0.74	0.03	0.01
14	0.04	0.20	0.17	0.18	0.28	0.25	0.19	0.11	0.02	2.00	0.07	0.01
15	0.04	1.50	0.18	0.17	0.36	0.21	0.23	0.08	0.02	0.20	0.07	0.08
16	0.18	4.00	0.15	0.16	7.60	6.00	0.16	0.06	0.03	0.06	0.03	0.01
17	0.52	1.00	0.15	0.15	1.20	6.50	0.19	0.52	0.02	0.03	0.03	0.01
18	0.25	0.40	0.15	1.50	0.65	0.94	0.18	0.11	0.02	0.02	0.03	0.01
19	0.34	0.25	0.23	0.58	1.20	0.57	0.14	0.07	0.01	0.02	0.02	0.00

Table C.7 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.18	0.20	0.19	3.40	0.69	0.39	0.13	0.12	0.01	0.01	0.01	0.00
21	0.13	0.17	0.15	2.00	0.46	0.29	0.61	0.10	0.01	0.17	0.01	0.00
22	0.09	0.87	0.12	0.67	0.82	0.25	0.67	0.08	0.02	0.26	0.38	0.01
23	0.08	0.98	0.10	0.41	0.58	0.22	0.32	0.06	0.01	0.12	0.13	0.00
24	0.07	0.44	0.09	0.54	0.38	0.20	0.22	0.05	0.01	0.04	0.05	0.00
25	0.07	0.30	0.07	1.10	0.28	0.18	0.16	0.04	0.01	0.02	0.03	0.00
26	0.06	0.25	0.07	0.60	0.25	0.16	0.12	0.07	0.01	0.01	0.02	0.00
27	0.06	0.24	0.06	0.39	0.23	0.15	0.10	0.65	0.00	0.01	0.01	0.00
28	0.05	1.50	0.05	0.30	0.20	0.14	0.54	1.60	0.00	0.01	0.01	0.00
29	0.05	0.61	0.11	4.50		0.18	0.29	0.58	0.00	0.01	0.04	0.00
30	0.05	0.35	0.43	1.30		0.21	0.18	0.18	0.00	0.01	0.04	0.00
31	0.09		5.10	0.57		0.18		0.09		0.01	0.01	

Table C.8. Daily streamflow at monitoring station GS17 (USGS 03537200) in Water Year 1990
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	1.6	0.04	0.1	0.31	0.14	0.1	0.07	1.9	0.04	0.15	0.01	0.01
2	0.28	0.03	0.09	0.15	0.13	0.26	0.07	0.48	0.04	0.06	0.01	0.01
3	0.14	0.03	0.07	0.12	2	0.3	0.07	0.32	0.05	0.02	0.01	0.01
4	0.09	0.03	0.07	0.22	1.6	0.18	0.06	1.5	0.04	0.01	0.02	0.01
5	0.07	0.03	0.06	0.22	0.3	0.14	0.06	0.35	0.03	0.01	0.13	0.01
6	0.05	0.2	0.06	0.25	0.21	0.11	0.15	0.19	0.03	0.01	0.06	0.01
7	0.04	0.33	0.05	0.22	0.19	0.1	0.14	0.13	0.03	0.01	0.02	0.01
8	0.04	0.4	0.12	0.58	0.13	0.11	0.11	0.1	0.03	0.01	0.04	0.01
9	0.04	0.26	0.09	0.31	0.18	0.12	0.1	0.16	0.09	0.01	0.3	0.01
10	0.03	0.13	0.08	0.17	1.8	0.18	0.12	0.24	0.07	0.01	0.16	0.01
11	0.03	0.09	0.08	0.13	0.33	0.19	0.1	0.15	0.03	0.03	0.05	0.01
12	0.03	0.07	0.09	0.11	0.2	0.15	0.08	0.11	0.03	0.35	0.03	0.01
13	0.03	0.06	0.08	0.09	0.16	0.12	0.08	0.09	0.02	0.25	0.02	0.01
14	0.03	0.08	0.07	0.08	0.12	0.11	0.09	0.07	0.02	0.57	0.06	0.02
15	0.03	0.59	0.07	0.07	0.14	0.1	0.09	0.06	0.02	0.08	0.04	0.07
16	0.07	0.95	0.06	0.07	2.3	1.7	0.07	0.05	0.02	0.04	0.02	0.01
17	0.15	0.19	0.06	0.06	0.39	2.1	0.08	0.16	0.02	0.02	0.03	0.01
18	0.08	0.12	0.06	0.37	0.22	0.31	0.08	0.06	0.02	0.02	0.03	0.01
19	0.1	0.09	0.08	0.19	0.34	0.21	0.07	0.05	0.02	0.02	0.02	0.01

Table C.8 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.07	0.08	0.06	0.96	0.25	0.16	0.07	0.08	0.02	0.02	0.01	0.01
21	0.05	0.07	0.05	0.64	0.18	0.13	0.21	0.06	0.02	0.09	0.01	0.01
22	0.05	0.2	0.05	0.22	0.24	0.11	0.28	0.06	0.03	0.1	0.11	0.02
23	0.04	0.25	0.05	0.15	0.2	0.1	0.14	0.05	0.02	0.06	0.05	0.01
24	0.04	0.16	0.04	0.17	0.16	0.1	0.1	0.04	0.01	0.03	0.03	0.01
25	0.04	0.12	0.03	0.28	0.13	0.09	0.08	0.04	0.01	0.02	0.02	0.01
26	0.03	0.1	0.05	0.21	0.11	0.09	0.07	0.05	0.01	0.01	0.01	0.01
27	0.03	0.09	0.05	0.15	0.1	0.08	0.06	0.18	0.01	0.01	0.01	0.01
28	0.03	0.4	0.04	0.12	0.09	0.08	0.13	0.42	0.01	0.01	0.01	0.01
29	0.03	0.21	0.06	1.3		0.09	0.08	0.2	0.01	0.01	0.03	0.01
30	0.03	0.13	0.11	0.42		0.09	0.07	0.09	0.01	0.01	0.02	0.01
31	0.05		1.4	0.19		0.08		0.06		0.01	0.01	

Table C.9. Daily streamflow at monitoring station GS1 (USGS 03536450) in Water Year 1990
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	8.2	0.4	1.1	2.7	1.8	0.93	0.68	6.7	0.57	1.4	0.23	0.27
2	3.5	0.26	1	1.9	1.6	1.8	0.66	3.2	0.52	0.48	0.23	0.25
3	2.1	0.26	0.92	1.6	7.8	1.4	0.63	2.8	0.53	0.3	0.23	0.24
4	1.6	0.25	0.79	2.2	8.3	1.3	0.61	5	0.45	0.27	0.45	0.23
5	1.3	0.24	0.71	1.8	3.7	1.2	0.59	3.2	0.41	0.24	1.7	0.23
6	1.1	1.2	0.65	1.9	2.5	1.1	0.94	1.9	0.40	0.26	0.63	0.22
7	0.99	1.7	0.6	1.7	2.1	1	0.7	1.5	0.38	0.26	0.37	0.21
8	0.8	2.5	0.97	3	1.7	1	0.66	1.4	0.38	0.28	0.46	0.21
9	0.61	1.7	0.65	2.3	2.3	0.97	0.63	1.7	1.00	0.27	1.7	0.21
10	0.49	1.3	0.61	1.9	7.6	1.2	0.75	1.6	0.67	0.24	0.9	0.20
11	0.44	1.1	0.6	1.6	3.5	1	0.67	1.2	0.47	0.71	0.62	0.19
12	0.39	0.97	0.66	1.3	2.3	0.99	0.63	1.1	0.43	2.2	0.53	0.22
13	0.37	0.8	0.6	1.1	1.8	0.98	0.6	1	0.39	1.6	0.31	0.21
14	0.36	0.81	0.56	1	1.5	0.95	0.65	0.99	0.40	2.8	0.9	0.44
15	0.34	4.3	0.56	0.9	1.5	0.94	0.64	0.97	0.38	1	0.6	0.44
16	0.7	4.9	0.52	0.81	8	5	0.7	0.98	0.35	0.67	0.38	0.21
17	1.2	2.5	0.48	0.72	3.8	9.1	0.89	1.7	0.34	0.49	0.45	0.19
18	0.8	1.8	0.45	2.4	2.6	4	0.8	0.97	0.34	0.38	0.38	0.17
19	0.98	1.4	0.57	1.4	2.6	2.6	0.75	0.94	0.35	0.36	0.33	0.21

Table C.9 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.8	1.3	0.48	3.8	2	2	0.7	0.96	0.35	0.32	0.3	0.20
21	0.54	1.1	0.44	3.4	1.7	1.6	0.83	0.89	0.34	1.7	0.4	0.28
22	0.4	1.9	0.41	2.4	2	1.4	0.78	0.86	0.46	1.2	1.2	0.25
23	0.34	1.5	0.38	1.8	1.7	1.2	0.73	0.83	0.30	0.75	0.62	0.18
24	0.35	1.2	0.39	1.9	1.4	1.1	0.81	0.81	0.29	0.54	0.55	0.17
25	0.34	1.2	0.4	2	1.2	1	0.91	0.81	0.27	0.37	0.46	0.16
26	0.35	1.1	0.44	1.5	1.1	0.92	0.87	0.95	0.24	0.31	0.36	0.14
27	0.33	1	0.41	1.4	1	0.83	0.84	1.4	0.23	0.28	0.31	0.14
28	0.33	2.1	0.38	1.4	0.98	0.76	1.2	1.8	0.24	0.25	0.27	0.15
29	0.34	1.3	0.39	4.9		0.77	0.89	1.1	0.24	0.24	0.86	0.16
30	0.32	1.2	0.93	3.3		0.78	0.83	0.97	0.20	0.24	0.4	0.14
31	0.45		4.9	2.3		0.72		0.77		0.25	0.3	

Table C.10. Daily streamflow monitoring at GS6 (USGS 03536320) in Water Year 1990
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	28	0.11	1.7	5.6	2.8	1.2	0.57	9.4	0.66	3.4	0.05	0.07
2	8.3	0.11	1.5	3.2	2.3	2.9	0.41	2.9	0.45	0.67	0.05	0.05
3	4.2	0.1	1.3	2.3	23	2.2	0.39	3.5	0.42	0.12	0.06	0.05
4	2.6	0.1	1.1	3.5	25	1.9	0.35	12	0.23	0.08	0.32	0.05
5	1.9	0.11	0.98	2.6	8	1.8	0.3	7.2	0.11	0.06	2.7	0.05
6	1.6	1.7	0.84	2.9	4.7	1.6	1.1	3.8	0.09	0.06	1.6	0.05
7	1.3	2.4	0.71	2.7	3.5	1.4	0.69	2.5	0.08	0.04	0.34	0.05
8	0.94	3.8	1.5	6.1	2.5	1.4	0.54	1.8	0.08	0.04	0.47	0.04
9	0.69	2.6	0.86	4.2	4.1	1.3	0.5	2.3	3.30	0.05	18	0.05
10	0.54	1.9	0.76	3	24	2.5	0.86	2.5	1.90	0.04	7.6	0.06
11	0.41	1.4	0.76	2.3	7.9	1.7	0.66	1.6	1.10	1.2	2.3	0.04
12	0.25	1.1	0.86	1.9	4.5	1.6	0.55	1.3	0.79	4.6	1.4	0.10
13	0.22	0.82	0.72	1.5	3.2	1.5	0.49	1.1	0.50	3.2	0.94	0.07
14	0.2	0.96	0.63	1.2	2.4	1.4	0.59	0.84	0.29	6.9	2	0.98
15	0.18	11	0.59	1	2.5	1.3	0.53	0.64	0.14	1.8	1.2	0.43
16	0.78	16	0.51	0.84	25	15	0.44	0.51	0.06	0.99	0.9	0.07
17	1.2	5.2	0.44	0.73	8.9	28	0.57	2.6	0.06	0.52	0.95	0.06
18	0.98	3.1	0.42	4.4	5.3	8.6	0.41	0.83	0.23	0.19	0.52	0.04
19	0.81	2.2	0.64	2.1	5.5	5	0.33	0.61	0.07	0.11	0.28	0.12

Table C.10 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.64	1.8	0.45	9.1	3.7	3.3	0.28	0.66	0.06	0.09	0.14	0.05
21	0.5	1.4	0.38	8.2	2.9	2.5	1	0.47	0.07	0.72	0.77	0.16
22	0.36	3.4	0.3	4.5	3.9	2	0.64	0.39	0.28	0.42	4.9	0.14
23	0.27	2.3	0.21	3.1	2.8	1.7	0.55	0.27	0.06	0.17	2.2	0.05
24	0.19	2	0.18	3	2.3	1.4	0.5	0.18	0.05	0.11	1.5	0.05
25	0.14	1.8	0.17	3.3	2	1.3	0.44	0.12	0.05	0.08	1.1	0.04
26	0.12	1.6	0.21	2.5	1.7	1.1	0.37	0.72	0.05	0.07	0.77	0.04
27	0.1	1.4	0.17	2.1	1.5	0.91	0.31	1.9	0.06	0.06	0.49	0.04
28	0.1	4.4	0.16	1.9	1.3	0.78	0.91	3.8	0.05	0.06	0.33	0.04
29	0.09	2.2	0.17	13		0.81	0.46	1.7	0.05	0.05	0.54	0.04
30	0.1	2	1.4	6.9		0.81	0.33	1.3	0.04	0.06	0.27	0.05
31	0.2		14	4		0.69		0.94		0.05	0.14	

Table C.11. Daily streamflow at monitoring station GS2 (USGS 03537100) in Water Year 1990
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	11	0.09	0.74	2.20	1.20	0.57	0.37	8.40	0.19	0.40	0.00	0.01
2	2.3	0.06	0.59	1.30	1.10	1.80	0.32	3.40	0.16	0.32	0.00	0.00
3	1.2	0.05	0.50	1.00	13.00	1.80	0.29	2.50	0.21	0.05	0.00	0.00
4	0.69	0.03	0.44	1.80	11.00	1.20	0.32	11.00	0.12	0.02	0.01	0.00
5	0.44	0.03	0.41	1.60	2.50	0.91	0.32	2.90	0.05	0.01	0.42	0.00
6	0.33	1.40	0.36	1.90	1.70	0.74	1.00	1.60	0.03	0.01	0.28	0.00
7	0.24	1.70	0.32	1.50	1.50	0.62	1.00	1.10	0.02	0.01	0.04	0.00
8	0.19	2.30	0.97	3.50	1.10	0.72	0.64	0.79	0.02	0.00	0.07	0.00
9	0.16	1.60	0.63	2.00	1.40	0.78	0.52	1.20	0.32	0.00	1.40	0.00
10	0.15	0.91	0.47	1.40	12.00	1.40	0.72	1.90	0.30	0.00	0.96	0.00
11	0.12	0.55	0.44	1.10	2.70	1.20	0.62	1.00	0.16	0.01	0.20	0.00
12	0.1	0.39	0.56	0.84	1.80	0.97	0.46	0.70	0.08	1.80	0.09	0.00
13	0.11	0.32	0.45	0.62	1.40	0.8	0.38	0.54	0.04	1.5	0.05	0.01
14	0.09	0.45	0.38	0.53	1.10	0.69	0.45	0.39	0.04	3.6	0.15	0.03
15	0.09	2.90	0.38	0.50	1.10	0.61	0.54	0.31	0.03	0.59	0.15	0.17
16	0.54	6.40	0.32	0.44	15.00	11.00	0.39	0.25	0.04	0.17	0.05	0.01
17	1.3	1.60	0.32	0.44	3.10	14.00	0.46	1.10	0.04	0.06	0.05	0.01
18	0.51	1.00	0.32	2.60	2.10	2.90	0.42	0.38	0.05	0.04	0.05	0.01
19	0.71	0.68	0.48	1.40	2.70	2.00	0.35	0.25	0.04	0.03	0.02	0.00

Table C.11 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.35	0.54	0.39	6.30	1.09	1.50	0.32	0.36	0.02	0.02	0.01	0.00
21	0.27	0.45	0.26	3.90	1.40	1.10	1.20	0.30	0.02	0.30	0.02	0.00
22	0.24	1.40	0.23	1.80	1.80	0.94	1.60	0.24	0.05	0.53	0.61	0.01
23	0.19	1.90	0.2	1.30	1.50	0.78	0.95	0.19	0.03	0.23	0.25	0.00
24	0.15	1.10	0.18	1.40	1.20	0.66	0.67	0.15	0.02	0.07	0.08	0.00
25	0.13	0.80	0.17	2.20	0.89	0.57	0.51	0.14	0.02	0.02	0.04	0.00
26	0.10	0.66	0.19	1.50	0.76	0.48	0.42	0.17	0.00	0.02	0.02	0.00
27	0.08	0.63	0.17	1.10	0.66	0.44	0.35	1.10	0.00	0.01	0.02	0.00
28	0.07	2.80	0.17	0.93	0.59	0.38	1.00	2.70	0.00	0.01	0.01	0.00
29	0.06	1.40	0.16	8.40		0.45	0.75	1.30	0.00	0.01	0.07	0.00
30	0.06	1.00	0.40	2.80		0.52	0.49	0.50	0.00	0.00	0.05	0.00
31	0.15		8.3	1.7		0.44		0.26		0	0.01	

Table C.12. Daily streamflow at monitoring station GS3 (USGS 03536550) in Water Year 1990
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	72	5.7	11	25	16	10	7.6	50	8.30	19	6.2	6.10
2	32	5.9	10	18	14	19	7.6	25	7.40	11	6.4	5.80
3	21	5.8	8.9	14	66	16	7.4	22	8.00	6.9	6.2	6.00
4	15	5.8	8.5	20	68	13	7.3	47	7.00	6.2	7.9	5.80
5	12	5.9	8.3	17	32	12	7	32	6.40	6.2	19	5.80
6	11	15	8.1	18	23	12	11	21	6.50	5.9	12	5.60
7	9.6	17	7.8	16	19	11	8.9	16	6.60	6.1	7.8	5.80
8	8.4	24	12	29	15	11	7.9	13	6.60	5.6	8.8	5.70
9	7.3	18	8.3	22	17	10	7.5	17	14.00	5.8	34	5.60
10	7.1	13	7.6	18	71	15	9.3	18	12.00	5.9	22	5.50
11	6.8	11	7.3	15	31	12	8.3	13	8.60	10	12	5.40
12	6.5	10	8.2	13	21	11	7.3	12	7.50	24	9.5	6.20
13	6.5	8.6	7.6	11	17	11	7	10	7.00	19	8.3	5.80
14	6.2	9.8	7	10	15	10	7.7	9.7	7.10	31	13	8.60
15	6	34	7.2	9.7	15	9.8	7.7	9.2	6.70	13	10	7.90
16	10	49	7.8	8.9	73	51	7.5	8.7	6.40	9.9	8.4	5.40
17	13	24	6.7	8.9	33	74	8.4	18	6.00	8.7	10	5.10
18	10	17	7.2	24	24	32	7.5	9.4	6.60	7.5	7.8	5.20
19	9.6	13	8.2	15	25	23	7	8.2	6.20	7.3	7.1	5.80

Table C.12 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	7.7	12	7.2	35	19	18	7.3	9	6.20	7.2	6.8	5.90
21	7.3	10	6.9	33	17	15	13	7.9	6.20	16	7.2	6.40
22	6.6	19	6.6	22	21	13	10	7.6	8.10	12	21	6.60
23	6.6	16	6.4	17	17	12	8.9	6.8	6.40	8.7	12	5.20
24	6.6	13	6.4	18	14	11	8.7	6.7	6.10	7.5	9.9	5.20
25	6.3	11	6.3	20	12	10	8.2	6.5	6.00	6.8	8.5	4.90
26	6.2	11	6.1	16	11	9.4	7.9	8.6	5.70	6.6	7.9	4.70
27	6	11	6.3	14	11	8.9	7.9	15	5.90	6.5	7	5.00
28	6.1	24	6.5	12	10	8.8	12	22	6.00	6.5	7	5.20
29	5.5	14	6.4	47		9	8.4	13	6.30	6.2	10	5.00
30	6	12	11	30		9	7.6	10	6.80	6.3	7.2	4.90
31	6.7		47	20		8		9.4		6.3	6.5	

Table C.13. Daily streamflow at monitoring station GS4 (USGS 03536440) in Water Year 1990
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	14	0.5	0.96	3.5	1.7	0.9	0.72	12	0.68	1.4	0.48	0.52
2	4.4	0.5	0.82	2	1.4	2.1	0.69	4.3	0.61	0.72	0.47	0.48
3	2.3	0.52	0.8	1.5	14	2	0.68	3	0.61	0.52	0.48	0.47
4	1.6	0.47	0.72	2.6	14	1.5	0.68	8.6	0.57	0.48	0.51	0.45
5	1.1	0.47	0.74	2	4.4	1.2	0.61	4.7	0.49	0.47	1.7	0.44
6	0.95	1.8	0.64	2.2	2.6	1.1	0.97	2.3	0.48	0.48	0.94	0.44
7	0.76	2.6	0.64	1.8	2	1.1	0.93	1.5	0.50	0.47	0.63	0.43
8	0.63	3.9	1.1	4.5	1.4	1	0.76	1.2	0.50	0.44	0.67	0.43
9	0.58	2.4	0.85	2.8	2	1	0.69	1.5	1.10	0.42	1.8	0.43
10	0.61	1.5	0.76	1.9	14	1.4	0.77	2.3	0.88	0.46	1.2	0.43
11	0.61	1.1	0.67	1.5	4.4	1.2	0.77	1.3	0.61	0.67	0.7	0.42
12	0.58	0.88	0.67	1.2	2.5	1.1	0.7	1	0.55	2.9	0.59	0.42
13	0.6	0.76	0.64	0.94	1.8	1.1	0.64	0.88	0.53	1.9	0.54	0.42
14	0.57	0.9	0.62	0.85	1.5	0.98	0.68	0.77	0.54	3.6	1.5	0.88
15	0.55	5.4	0.62	0.78	1.5	0.95	0.7	0.7	0.53	1	0.98	0.56
16	0.75	8.8	0.6	0.72	16	10	0.65	0.63	0.48	0.7	0.66	0.43
17	1.4	2.8	0.56	0.66	5.1	16	0.74	1.7	0.47	0.64	0.73	0.42
18	1	1.7	0.6	3.1	3	4.9	0.8	0.74	0.47	0.57	0.62	0.42
19	1.1	1.2	0.74	1.7	3.5	2.9	0.72	0.63	0.47	0.56	0.57	0.45

Table C.13 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	0.8	1	0.71	6.4	2.3	2	0.72	0.65	0.47	0.59	0.61	0.44
21	0.65	0.88	0.68	5.4	1.9	1.6	0.94	0.53	0.47	2.2	0.61	0.49
22	0.58	2	0.66	2.7	2.4	1.3	1	0.52	0.56	1.7	1.1	0.49
23	0.57	1.8	0.65	1.9	1.9	1.2	0.81	0.48	0.49	1.1	0.74	0.44
24	0.6	1.2	0.64	1.8	1.5	1	0.8	0.48	0.44	0.75	0.66	0.41
25	0.61	1	0.64	2.6	1.2	0.95	0.73	0.48	0.44	0.66	0.6	0.45
26	0.61	0.94	0.63	1.8	1.1	0.87	0.66	0.53	0.44	0.58	0.57	0.47
27	0.58	0.88	0.61	1.4	1	0.87	0.66	1.3	0.48	0.55	0.56	0.44
28	0.52	2.8	0.53	1.1	0.9	0.78	1.1	2.6	0.50	0.5	0.54	0.46
29	0.5	1.5	0.58	8.6		0.79	0.87	1.4	0.52	0.47	0.85	0.44
30	0.5	1.1	1.1	4.2		0.8	0.7	0.94	0.50	0.47	0.68	0.44
31	0.59		9.8	2.3		0.75		0.76		0.51	0.56	

Table C.14. Daily streamflow at monitoring station GS4 (USGS 03536440) in Water Year 1990
units=cfs

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
1	49	3.1	6.2	15	9.2	5.3	4.2	23	4.3	14	2.6	2.9
2	20	3.1	5.5	9.8	8	11	4	12	3.9	5.3	2.5	2.9
3	12	2.9	4.9	7.9	52	8.6	3.9	13	4.1	3.3	2.5	2.8
4	9	2.9	4.5	12	58	7.3	3.8	28	3.5	3	3.8	2.6
5	7.3	2.9	4.3	9.1	20	6.8	3.8	18	3.4	2.9	11	2.5
6	6.3	8.3	4	9.9	13	6.1	6.5	12	3.3	2.8	6.5	2.5
7	5.2	9.5	3.9	9	11	5.8	4.8	8.7	3.3	2.7	3.9	2.5
8	4.6	13	6.4	17	8.7	5.8	4.3	6.9	3.2	2.5	4.8	2.5
9	4	9.7	4.2	12	12	5.5	4.1	8.9	9.4	2.6	26	2.5
10	3.7	7.2	3.8	9.7	46	8.7	5.1	9.3	6.5	2.6	16	2.5
11	3.5	5.9	3.8	8.1	18	6.7	4.3	6.6	4.7	5.7	7.4	2.5
12	3.3	5.3	4.1	6.7	13	6.4	3.9	5.8	4.2	14	5.6	2.8
13	3.3	4.4	3.8	5.7	10	6	3.9	5.5	3.9	12	4.7	2.6
14	3.2	5.2	3.6	5.1	8.4	5.7	4.4	4.8	3.7	20	7.3	4.2
15	3.1	24	3.6	4.9	8.6	5.5	4.1	4.6	3.5	7.2	5.5	5.2
16	5.3	36	3.4	4.5	49	33	3.9	4.4	3.3	5.3	4.5	2.6
17	6.9	14	3.3	4.4	20	51	4.2	10	3.2	4.4	5.4	2.5
18	5.6	10	3.2	14	14	19	3.6	4.8	3.5	3.8	3.9	2.4
19	5.1	7.6	4.1	7.7	15	14	3.4	4.2	3.2	3.6	3.4	2.8

Table C.14 (continued)

DAY	OCT89	NOV89	DEC89	JAN90	FEB90	MAR90	APR90	MAY90	JUN90	JUL90	AUG90	SEP90
20	4.2	6.6	3.4	22	11	10	3.4	4.7	2.9	3.5	3.2	2.9
21	3.7	5.7	3.2	19	9.6	8.6	7.9	3.8	2.9	7.6	4.2	3.3
22	3.5	11	3	13	12	7.4	5.2	3.7	4.1	5	15	3.2
23	3.4	8.6	2.8	9.5	9.5	6.8	4.7	3.4	3.0	3.8	7.9	2.7
24	3.3	7.1	2.8	9.8	8.1	6.2	4.5	3.3	2.9	3.4	5.8	2.5
25	3.1	6.4	2.9	11	6.9	5.8	4.3	3.1	2.8	3.1	4.8	2.3
26	3.1	5.9	3	8.6	6.3	5.2	3.9	4.7	2.9	2.9	4.1	2.2
27	3	5.8	2.9	7.5	6	4.8	3.8	8.3	2.7	2.9	3.6	2.2
28	2.9	13	2.9	6.9	5.6	4.7	6	13	2.8	2.8	3.4	2.2
29	2.9	7.6	2.9	28		4.8	4	7	3.0	2.7	5	2.2
30	3	6.9	6.4	17		4.9	3.6	5.3	3.1	2.7	3.4	2.1
31	3.7		30	12		4.3		4.7		2.7	3	

Appendix D

Summary Statistics for Groundwater Well Water Levels in Whiteoak Creek Watershed

Table D-1. Summary of water levels in groundwater wells located in the WOC watershed

WELL ID	EASTING	NORTHING	MAXIMUM WATER LEVEL	MEAN WATER LEVEL	MINIMUM WATER LEVEL	NO. OF OBSERVATIONS
65	25945	18988	805.2	805.2	805.2	1
84	26224	17162	763.12	763.12	763.12	1
114	26433	18148	806.85	806.85	806.85	1
276	23895	16211	757.95	757.2433	756.18	9
318	24323	17225	789.89	789.89	789.89	1
345	24881	16361	754.34	753.5611	753.15	9
347	24604	16531	772.43	771.1622	769.44	9
356	24451	16481	761.97	760.9344	759.65	9
368	25155	17348	794.65	794.2722	793.91	9
371	25090	16393	747.835	746.3451	745.924	59
382	24025	15814	747.833	746.6088	746.151	71
386	24828	16892	777.526	777.0326	776.46	99
533	28818.67	22006.67	792.07	792.07	792.07	1
538	29736.18	22630.29	799.86	799.86	799.86	1
539	29807.39	22379.31	797.96	797.96	797.96	1
541	29816.1	21829.32	785.65	785.65	785.65	1
551	30143.66	22067.42	794.99	794.99	794.99	1
553	30243.72	21584.37	786.58	786.58	786.58	1
558	30699.55	22800.03	869.54	869.54	869.54	1
560	30700.18	22447.75	817.55	817.55	817.55	1
561	30659.54	22190.16	807.06	807.06	807.06	1
566	30625.08	21755.47	791.39	791.39	791.39	1
569	30545.59	21037.77	775.32	775.32	775.32	1
575	31698.83	23233.55	821.85	821.85	821.85	1
579	30919.87	21640.4	784.36	784.36	784.36	1
592	31108.27	21933.86	790.08	790.08	790.08	1
596	31384.8	22660.72	806.3	806.3	806.3	1
600	31475.14	21719.22	784.48	784.48	784.48	1
601	31503.38	21497.54	783.27	783.27	783.27	1
604	31521.98	22039.86	796.69	796.69	796.69	1
609	36680.22	21696.92	830.18	830.18	830.18	1

Table D-1 (continued)

WELL ID	EASTING	NORTHING	MAXIMUM WATER LEVEL	MEAN WATER LEVEL	MINIMUM WATER LEVEL	NO. OF OBSERVATIONS
611	31790.15	22790.02	806.9	806.9	806.9	1
613	31656.13	22305.48	798.37	798.37	798.37	1
615	31864.64	22334.92	797.14	797.14	797.14	1
623	31949.52	21945.64	789.71	789.71	789.71	1
627	32171.4	21410.94	783.06	783.06	783.06	1
630	32277.67	22310.73	800.65	800.65	800.65	1
633	32560.46	22304.59	803.35	803.35	803.35	1
636	24326.17	17668.04	805.9	803.3544	801.11	9
640	24719.55	17614.7	805.29	804.2225	803.18	4
642	24035.55	16580.96	773.25	771.12	769.01	10
644	24848.36	16748.86	772.408	770.5577	769.71	99
645	25274.6	17173.65	759.78	759.07	758.46	8
646	25167.05	17550.78	772.52	771.8538	770.98	8
647	24749	17145.66	788.44	787.6856	787.1	9
648	24524.24	17374.55	801.01	799.3878	797.98	9
649	25075.5	17375.49	0	0	0	0
650	25150.16	17273.53	0	0	0	0
650	25150.16	17273.53	0	0	0	0
653	24070.4	15792.51	748.242	746.6251	746.208	85
654	24054.76	16618.16	775.06	773.9544	772.36	9
655	24815.3	17469.72	801.65	799.4667	797.44	9
656	24692.96	17923.92	813.9	810.8633	807.67	9
658	32442.11	16957.54	809.3	809.3	809.3	1
661	32699.2	16746.67	794.88	794.88	794.88	1
669	28407.98	17389.37	756.6	756.6	756.6	1
670	31450.94	18697.47	814.04	814.04	814.04	1
675	31493.5	18486.97	802.58	802.58	802.58	1
678	27727.56	18663.22	822.45	822.45	822.45	1
684	28065.81	19602.19	827.97	827.97	827.97	1
685	28049.72	19399.76	807.65	807.65	807.65	1

Table D-1 (continued)

WELL ID	EASTING	NORTHING	MAXIMUM WATER LEVEL	MEAN WATER LEVEL	MINIMUM WATER LEVEL	NO. OF OBSERVATIONS
686	28050.41	19200.06	789.39	789.39	789.39	1
687	28031.11	19028.51	780.95	780.95	780.95	1
698	26771.19	21937.72	818.86	818.86	818.86	1
705	24548.26	21837.32	820.92	820.92	820.92	1
710	30001.07	17185.24	793.81	793.81	793.81	1
715	29589.45	18752.99	805.12	805.12	805.12	1
716	29205.86	18535.72	773.91	773.91	773.91	1
718	26783.99	18863.66	805.57	805.57	805.57	1
721	29297.12	21033.45	775.74	775.74	775.74	1
723	29553.92	19832.63	769.34	769.34	769.34	1
740	23372.39	15778.95	751.06	751.06	751.06	1
758	31230.27	16685.4	775	775	775	1
762	32343.13	16307.21	783.02	783.02	783.02	1
764	37026.93	21925.57	838.73	838.73	838.73	1
766	29429.25	16857.05	760.03	760.03	760.03	1
767	29443.86	16858.83	764.05	764.05	764.05	1
782	27367.38	16671.83	751.49	751.49	751.49	1
783	27388.4	16681.18	752.51	752.51	752.51	1
790	24944.39	21491.53	832.11	832.11	832.11	1
793	24560.55	21463.35	825.75	825.75	825.75	1
905	37303.77	21606.94	839.43	839.43	839.43	1
912	37447.46	18839.08	873.51	873.51	873.51	1
916	37374.17	18412.45	843.09	843.09	843.09	1
1027	31623.78	17460.46	819.13	819.13	819.13	1
1030	32331.37	18938.94	837.15	837.15	837.15	1
1033	30573.8	19135.18	817.51	817.51	817.51	1
1114	35400.49	15874.99	821.48	819.7945	817.07	11
1115	35414.09	15893.39	819.6	818.354	815.63	10
1117	35737.03	15810.46	827.9	827.9	827.9	1
1118	36179.71	15839.43	840.23	838.3891	835.6	11

Table D-1 (continued)

WELL ID	EASTING	NORTHING	MAXIMUM WATER LEVEL	MEAN WATER LEVEL	MINIMUM WATER LEVEL	NO. OF OBSERVATIONS
1119	36175.41	15817.77	840.45	838.7945	835.95	11
1120	36120.5	15545.04	839.36	838.0244	836.22	9
1121	35919.14	15531.59	832.57	832.57	832.57	1
1122	35936.04	15526.85	833.36	833.36	833.36	1
1123	36643.41	15559.14	856.49	853.04	847.07	11
1124	36663.17	15562.38	857.56	854.597	850.37	10
1125	36425.41	15224.32	831.74	831.74	831.74	1
1126	36403.34	15230.49	844.24	844.24	844.24	1
1127	36599	15238.43	851.29	846.8691	842.68	11
1128	36618.53	15243.46	851.28	842.7364	836.61	11
1129	36838	15188.67	846.29	846.29	846.29	1
7-1	34551.4	17940.4	881.3	876.044	871.48	10
7-10	33799	17215.1	834.38	831.138	827.08	10
7-11	34191.3	17145.1	838.8	833.059	828.29	10
7-12	35614.7	18038	875.76	873.402	870.43	10
7-13	33757.8	16159.6	796.24	795.632	794.98	10
7-17	35172.5	16887.6	866.22	866.22	866.22	1
7-18	35236	16858.1	861.55	861.55	861.55	1
7-3	35534.5	17034.6	849.19	849.19	849.19	1
7-4	35158.2	16930.3	869.75	867.0927	863.33	11
7-5	34885.2	16678.7	839.54	836.6436	834.27	11
7-6	34841.7	16308.8	828.65	823.6755	819.23	11
7-7	34706.9	16055.7	806.33	805.6018	804.73	11
7-8	33181.6	16314.8	796.77	794.666	791.35	10
7-9	33663.5	16771.4	828.89	823.485	819.02	10
CR-13A	22772.53	25391.6	918.48	907.647	898.28	10
CR-13B	22728.8	25373.5	915.57	906.079	897.41	10
CR-14A	23970.27	25358.22	959.33	954.536	951.4	10
CR-14B	23951.2	25328.55	925.15	916.991	909.47	10

Table D-1 (continued)

WELL ID	EASTING	NORTHING	MAXIMUM WATER LEVEL	MEAN WATER LEVEL	MINIMUM WATER LEVEL	NO. OF OBSERVATIONS
CR-15A	23333.63	25000.04	926.39	914.777	904.49	10
CR-15B	23352.66	24987.59	925.59	914.599	904.41	10
SB-2	27630.2	17619.5	780.5	780.5	780.5	1
412	25687	17309	768.86	768.86	768.86	1
419	26564	17342	775.49	775.49	775.49	1
WT7-3	27785	17223	762.8	762.8	762.8	1

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